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THE "HOUSE OF THE GARDEN," TIMGAD. THIS, THE DWELLING OF SOME WEALTHY ROMAN, HAD ITS COURT PARTLY SURROUNDED BY A RAISED FLOWER GARDEN.

A BYZANTINE BASILICA IN TIMGAD. THERE ARE SEVEN BYZANTINE CHURCHES IN THE CITY, BUILT IN PART OF MATERIALS PLUNDERED FROM FORMER ROMAN BUILDINGS.

ROMAN CITIES OF NORTHERN AFRICA.—[SEE PAGES 232, 233 AND 234.]

HOW TO PREVENT FAILURE IN CONCRETE CONSTRUCTION.*

AN EXPERT ANALYSIS OF AN IMPORTANT PROBLEM.

BY DR. W. MICHAELIS, JR., M.W.S.E.

In the following I wish to present my views on the merits and limitations of cement and concrete and on the causes of failure in concrete construction, and will suggest means for the prevention of such failures. In doing so I will discuss this subject as a consulting engineer who is familiar with both the details of the manufacture of cement, and its chemical and physical properties, and with the use of cement as building material, and will endeavor to point out what can be expected of cement and what not. The manufacturer frequently greatly exaggerates the advantages of cement. On the other hand, the engineer and architect, who are frequently not acquainted with the intrinsic value of cement with its physical and chemical properties, frequently make unreasonable demands and misinterpret the failures in concrete construction that unfortunately so often occur. To my mind, the best and surest way to advertise cement, to recommend concrete construction, and to give the engineer and architect confidence in this modern building material, would be to minimize the danger of failure as far as possible by proper building ordinances, which would compel the contractor to handle the material in a prescribed way, and to make proper tests.

Concrete is a wonderful material in the hands of a skillful contractor, and has many advantages over other building materials; but it is the unsafest of all materials, if it is handled by an inexperienced, careless and dishonest builder.

I shall dwell only in a general way on the wide possibilities of concrete construction and point out a few cases where concrete cannot be used:

Concrete offers great resistance to compression, but only comparatively slight resistance to tension. Therefore we can make use of plain concrete in cases in which it is subjected chiefly to compressive stresses, as in foundation work, walls, piers, and columns. Where it has to resist tensile stresses, as in girders, beams, and floors, we have to reinforce it with steel of high tensile strength. The union of concrete and steel thus obtained can be made to fulfill any requirements as to compressive and tensile strength, according to the greater or lesser amount of concrete or steel used in each special case. In some cases the compressive strength of the steel is made use of at the same time as its tensile strength, namely, when the dimensions of the concrete work have to be reduced to a minimum, as often in columns and piers.

Piers and columns are often reinforced by plain round rods, placed near the circumference and connected by wire or ties. This kind of reinforcement is liable to be the cause of disaster, if an insufficient percentage of reinforcement is used, either in the designing or by negligence of the contractor, who may omit some of the bars. Columns insufficiently reinforced by bars, fail suddenly by pushing the steel rods apart. A safer way of reinforcing columns is to make use of spiral reinforcement. Such columns fail by bending and give ample warning before failure. There is a creaking noise of the compressed concrete and scaling off of the concrete on the surface of the columns; then the column is slowly bent out of shape before it collapses. This kind of reinforcement, therefore, should be used exclusively for columns which have to sustain heavy loads. Girders and beams are reinforced by tension rods which are imbedded in those parts of the concrete which are subjected to tensile stresses. The reinforcement consists either of several single bars, horizontal and partly turned up, which are held in place by stirrups or U-shaped iron, or by bars which present a rigid combination of bar and stirrups. This latter method is much safer, because it makes it impossible for the contractor to omit some of the stirrups; moreover, all parts must necessarily maintain their relative positions with respect to one another and chances of defective work from faulty placing of steel are largely avoided. Floors and ceilings are likewise reinforced by steel rods imbedded in the lower part of the layer of concrete to take up the tensile stresses.

In all cases the mechanical laws that govern this type of construction are the same as in steel construction; therefore the methods of calculation are the same. The only difference is that in steel construction we have to deal with but one kind of material, while in reinforced concrete construction we have to figure with two kinds of materials of entirely different physical properties. Of these we let the concrete as a rule take care of itself, whenever compressive strength is required, and call upon the steel reinforcement only where tensile stresses occur.

Modern methods of reinforced concrete construction frequently make building possible on grounds on which other material cannot be used. For instance, in places where wooden piles would rot, reinforced concrete piles are driven, and on sites where the soil cannot be depended upon, as on river banks and sea shores, a solid foundation is obtained by a reinforced concrete raft, which transmits the load over the whole available area, and which, owing to its rigidity, does not give way, even if there should be a settlement of the ground at any particular point. The monolithic connection of foundations, columns, girders, beams and floors, on account of its unequaled rigidity, is a decided advantage over the freely supported girders and beams of wood and steel construction. This is particularly true in places where earthquakes have to be considered. However, concrete cannot be used everywhere, as there are some limitations to its use. In some parts of the country cement is too expensive, or good sand or crushed stone cannot be obtained. In others the high cost of lumber for forms excludes concrete construction. This latter point becomes more and more serious from year to year with the growing advance in the price of lumber. The cost of the wooden false-work, and the labor cost of installing and removing it amounts sometimes to 50 per cent of the cost of the structure. In such cases another method has been adopted, which does away with a large part of the lumber, namely, the casting on the ground of columns, beams, girders, and floor slabs, which are afterward hoisted and erected as with structural steel work. This saves the centers and supports and reduces the cost of erection, but at the same time it sacrifices the main advantage of concrete structures, namely, their monolithic character.

The erection of a concrete building, as a rule, takes considerably more time than that of a steel structure, at least if it is done with care, and if all parts are given plenty of time to set before removing the forms. This is a serious item in the cost of the building, in case of a large office building or hotel, because every month which it takes longer to erect the structure means a considerable loss in rental from the building. Some cases, however, have been pointed out where the erection of a concrete office building has not required more time than that of a steel skeleton building. But such practice is dangerous, and should not be approved, unless the contractor can demonstrate by continuous tests that the concrete work is strong enough to sustain the superimposed load, and that he is justified in removing the forms.

The principles governing modern reinforced concrete construction are thoroughly understood by comparatively few. This explains the divergence of opinion on many points pertaining to this branch of the building industry. While some engineers are careful to specify concrete of ample strength, others blame such "over-cautious" builders for making use of an excessive factor of safety. The aim is, of course, to reduce the cost of concrete as far possible in order to give it the widest application possible. But if engineers fail in their efforts to prove that for a given case, concrete work would be less expensive than steel construction, they frequently blame the cement for it. They will say, for instance, that cement is not sufficiently uniform at present, and they claim that if cement could be so manufactured as to give as uniform tests as does steel, it would be possible for the engineer to reduce the larger factor of safety now demanded for concrete over that required for steel. Such a statement is entirely without foundation. Cement is manufactured of sufficient uniformity nowadays, at least by plants which can depend upon uniform raw materials. Cement can be manufactured as uniform in quality as steel. But in comparing the cost of steel and concrete construction and their respective safety factors, we are not allowed to compare steel with cement, but steel with concrete. Steel is a well-defined chemical compound rolled into the desired shape. Concrete, on the other hand, is the sum of a number of factors, namely, of cement (a chemical compound equally well defined as steel, and ground to the desired fineness), of crushed stone, of sand, of water, of workmanship, and of a great deal of care, a combination of which cement is a comparatively small part. The calculation of a steel girder and that of a reinforced concrete girder or beam can never be based on equal safety factors, no matter how much the properties of cement may be improved in the future.

Moreover, cement will not be improved in the future; we have arrived at the limit of its good qualities. In making this statement, I refer to Portland cement, of which every builder in this country thinks, whenever the general term "cement" is used. Why can Portland cement not be improved? In order to be able to answer this question, I must remind you that Portland cement is a product obtained by calcination of an intimate mixture of finely pulverized limestone and clay or shale, and that it consists of calcium silicates and calcium aluminates. Clay and limestone may be mixed in all possible proportions, but the result from a chemical standpoint will never be anything better than our present commercial Portland cement. Then, if the chemical composition of Portland cement cannot be improved, cannot its physical properties be altered, can it not be ground more finely? Yes, this latter can be done, indeed, but it would not be of any practical value.

Recent investigations have proven that of our commercial Portland cement only from 30 to 40 per cent possesses cementing properties at all; the remaining 60 to 70 per cent represents inert material. Until a short time ago, you could read in cement literature that the cement remaining on a 200-mesh sieve is too coarse, that is to say, has no hydraulic properties, and that everything that passes the 200-mesh sieve represents the active part of the commercial cement. To-day the 200-mesh sieve exists only for the manufacturer in order to enable him to grind his clinker always to a certain fineness required by the specifications. The experimenter, however, can no longer make use of so coarse a screen as a 200-mesh sieve. He divides the cement into that part which remains on an 800-mesh sieve, which is inert (about 60 to 70 per cent), and that which passes the 800-mesh sieve (30 to 40 per cent), which is cement proper. Of course, an 800-mesh sieve does not exist. It would have meshes one sixteen-hundredth of an inch wide and would consist of wire gauze of the same thickness. In order to obtain this fineness, the imaginary sieve is replaced by a process of decantation or elutriation in a current of alcohol of a certain velocity which separates the fine from the coarse and leaves the grains that measure more than one sixteen-hundredth of an inch under the microscope. If the manufacturer would grind his Portland cement to this extreme fineness or even only to a fineness between the 800-mesh sieve and that of the commercial cement of to-day, say to 70 per cent passing an 800-mesh sieve, the resulting product would be so quick-setting a cement that nobody would be able to use it in practice. A neat or a sand mortar briquette may be made of it possessing a strength several times higher than the strength obtained from Portland cement of the present fineness, but this is only under the assumption that the mortar be gaged with the water less than a minute. If the gaging should continue for several minutes, no higher strength than for ordinary cement can be obtained. This is due to the quick-setting qualities of the calcium aluminates in the Portland cement. No addition, however great, of any retarding element, can prevent this. So finely ground a Portland cement, therefore, could not be used in actual practice, where under the best conditions a quarter of an hour is required from the time of mixing the concrete until it is tamped into the forms or molds. I have frequently made such experiments with cement of extreme fineness separated from the coarser particles by an air-current for instance, with cement that had been collected on the top of a 30-foot ventilating tube over grinding machinery, and from these experiments I know that such Portland cement will never fulfill the demands of engineers and architects who are eagerly looking for a cement of higher crushing strength than our present Portland cement. Architects rightly wish, both for economic and mechanical reasons, to disuse reinforcement in concrete columns. As long as they make use of Portland cement for their concrete, they will have to design columns of enormous proportions, if they want to omit reinforcing bars or spiral reinforcement. Therefore the desire for a much better grade of cement, which according to a recent utterance of a well-known engineer, "would receive an enthusiastic reception by all engineers." Fortunately such a cement exists.

The cement to which I refer is "Iron Ore Cement," which has been manufactured for several years in Germany, and which I hope will soon be manufactured in the United States also. This cement is made of limestone and iron ore instead of using limestone and clay as in the manufacture of Portland cement. It was originally manufactured with the sole intention of replacing Portland cement for sea-water construction, because Portland cement is rapidly destroyed by the magnesia sulphate contained in the sea-water, while iron ore cement is not acted upon by even the most

* Abstracted from a paper read before the Western Society of Engineers.

concentrated solution of sulphates. This iron ore cement, if ground to the fineness of commercial Portland cement, is very slow setting, because of its chemical composition, which differs from that of Portland cement inasmuch as the aluminates of the Portland cement are replaced by iron compounds, by calcium ferrites. The aluminates of the Portland cement, as mentioned above, are the cause of its quick-setting properties. The calcium ferrites of the iron ore cement, however, hydrate slowly, so that this cement has a comparatively low strength after a day or a week. But its strength steadily increases from month to month and year to year, soon reaches that of Portland cement and in time far exceeds its maximum strength, so that a barrel of iron ore cement goes much farther than a barrel of Portland cement even under ordinary conditions; that is to say, if both are ground to the same fineness as at present. Now let us grind iron ore cement to extreme fineness, which can easily be done by air-separation; it will finally become as quick-setting as commercial Portland cement is now, it will contain perhaps 70 to 80 per cent of active material as compared with the 30 to 40 per cent of Portland cement of the same setting properties. A barrel of such finely pulverized iron ore cement will replace three barrels of Portland cement and will enable the architect either to use leaner mortars or to considerably reduce the dimensions of columns and beams. As mentioned before, this cannot be done with Portland cement. Moreover, a better grade of cement could be shipped farther, as the consumer would obtain in one barrel of cement the same amount of cementing material as is contained in three barrels now.

I will now discuss how, with materials at present available, the frequent deplorable accidents can be prevented. As said before, cement is manufactured so uniformly and is generally tested so thoroughly at the plants before being shipped, that only in comparatively few cases is the cement to blame for the failure of concrete work. In most cases the builder has himself to blame for the collapse of a structure. In work of minor importance, for instance in sidewalk work or in the manufacture of concrete blocks, failures can be noticed every day. Where cement is thus used on a comparatively small scale, cases happen where failure is due to poor cement, as usually only the consumer of large quantities of cement makes tests of his own and can find out in advance whether or not he has received a reliable product from the manufacturer. Thus it sometimes really happens that a small consumer receives a carload of cement, which has not the proper setting time, and which he kills in working it. Cement companies who have not uniform raw materials or whose materials are too high in alumina often have trouble in regulating the setting time and they supply the consumer now and then with a cement with which he is unable to work. To this group of manufacturers likewise belong those companies who do not pay enough attention to thorough vitrification of the clinker. If the clinker is merely burnt to a point of beginning vitrification, if a friable clinker is obtained which just passes the specifications after a little curing and doctoring, it happens that this cement disintegrates after having been shipped, changes its setting properties and becomes a quick setting cement, while it may have had a medium setting time when it had been tested at the works. In using the term "disintegrate" in this case I do not refer to the dusting, on cooling, of overburnt clinker, or clinker too high in silica, but to the breaking up into smaller fragments which every clinker shows on aerating, unless it is burnt to a dense, vitrified piece of rock. Such a cement if ground at the factory like all others to the fineness of a commercial cement—about 30 or 40 per cent of it would pass the 800-mesh sieve, when it is tested before leaving the plant. But it continues to disintegrate after being packed in sacks or paper bags; the moisture of the atmosphere breaks up every little particle into smaller fragments, and in time a much higher percentage of the extremely fine powder is found than when shipped, and the result is that the cement which may have set in two or three hours when tested at the plant, now begins to set instantaneously. There are few consumers of cement or even chemists and superintendents of cement plants who are able to detect this. If you give them a cement which begins to set in 5 or 10 minutes, they will find it out, but if they get hold of a cement which sets immediately, they frequently do not discover the fact, and afterward wonder at the poor results obtained with it. Some six years ago commercial cements of even the largest plants could frequently be found to set instantaneously, although the men at the works were not conscious of the fact. But nowadays such cases become more and more rare, and we may safely say, that in nine out of ten cases the consumer of cement is to blame, if we consider only sidewalk work or the manufacture of concrete blocks. In these branches of the business we see any number of incompetent people engaged, who handle a few dozen barrels of cement a day, who cannot be expected to make elaborate tests of cement, and who would not be able to make them correctly, even if they wanted to. In all other cases, where work of larger proportions is involved, namely, in the construction of residences, factories, office buildings and hotels, the manufacturers of cement can never be blamed for failure during the course of construction, because it is the business of the builder to test his cement thoroughly before using it. The building ordinances of all States should compel builders to submit the cement to thorough tests before using it, no matter how well-known a brand of cement they may have bought. Such a law would obviate the few possible cases, where cement might otherwise be blamed for destructive failures. After this has been settled we would have to consider how the many failures can be prevented where the builder himself is at fault.

In order to understand the situation we have to ask at first: In what respect do masonry and steel construction and concrete construction differ? The old-fashioned way is to erect structures of material of known strength as by piling brick of a certain compressive strength, one on the top of another, to construct walls and piers, and then to connect the piers by means of wooden or steel girders and beams of known strength. In steel structures the masonry piers are replaced by steel columns to which are securely riveted steel girders and beams which carry the floors. In this class of construction comparatively few failures can occur, if the designs have passed through the hands of a careful board of building examiners, and if the material, brick, steel, and wood, conform to the specifications. The members may be jointed and riveted together in a negligent way; but this can easily be detected by building inspectors and careless work can be replaced. In concrete construction, on the other hand, the strength of none of the members of which the structure is composed is known in advance. The designs may have passed through the hands of competent and careful examiners, who may have scrutinized every detail of the construction and found it to conform to other previous designs which have proved a success, and yet the erection of the building may result in complete failure and great loss of life. No other building material is apt to result in destruction of equal magnitude, if handled carelessly. All that the builder of concrete work knows, when starting to carry out the design before him, is the strength of the cement and that of the reinforcing bars, if he has gone at all to the trouble of having both examined, one for crushing stress and the other for tensile strength. Then he proceeds to erect the forms and supports, mixes crushed stone, sand, and cement in certain proportions, and tamps the concrete into the molds. After a certain time he comes to the conclusion that the concrete has had time enough to set, that he needs the centering at some other part of the building, and orders his men to remove the forms; and in many cases it is more or less of a pleasant surprise to him, if the building does not collapse on striking the forms. Experienced contractors who can depend upon a well-trained gang of workmen, and have reliable men to superintend the work, will be able to tell quite well how much of a load a column or beam will stand after a certain time, but with most contractors it is only guesswork, and such a state of affairs should not be tolerated.

Those who know how little attention is frequently paid to thorough mixing of concrete and with what haste the work is done, will understand that poor concrete is a very common cause of failure. The work is often done automatically; crushed stone, gravel, sand, and cement are fed into the mixer in the desired proportions from individual hoppers. Unless the supervision is very severe in such a case, it may happen that one of the hoppers chokes and the material flows less freely, thus entirely changing the proportions of the concrete. Such unintentional mistakes amply suffice to bring about disaster; but if to these intentional carelessness is added, and the concrete is weakened willfully, hardly anything but failure can be the result.

Weaknesses in the design or in the concrete work may be present in any concrete construction, and the contractor can never be absolutely sure that his building will not collapse on removing the woodwork from under the floors and girders, as long as he proceeds in the way he has so far. The time of removal of the centering is the critical one and the time when accidents are most likely to happen. In many cases the forms are removed when the concrete is still quite soft; it may not have had time enough to harden, or the concrete may have been spoiled while being mixed, or concrete partly hardened may have been stirred up again and mixed with additional concrete. The reasoning of the contractor will generally be, that it has had time enough to harden and that the forms and supports must come down, because they are needed at some other part of the building. Moreover, a floor that may have set for a sufficiently long time to carry its own dead load, has frequently to carry the supports and floors of one, two or even three stories above it, which are in the course of construction. The floor may not have been designed for such a load at all or at least it cannot be expected to carry several times its own dead load after so short a time, but nevertheless the contractor will strike the centering, when he should know that the collapse of the floor panel is almost inevitable.

In my opinion failures can materially be lessened, if not entirely be prevented, by proper building ordinances which make it compulsory to use concrete of specified proportions of crushed stone, sand, and cement, to use the proper kind of reinforcement in each case, and the necessary amount of it. Certain standard rules should be laid down by a board of building examiners, and certain types of reinforcing material should be excluded where they are not in their proper place. In addition to these points, which refer to the designing of the structure, the erection of the building should be accompanied by continuous tests of the concrete that goes into the construction, and the builder should be compelled to inform himself of the strength of each column, girder, beam, and floor slab before striking the forms and placing the load upon them. In the following let me explain to you what I mean by this, and let me illustrate how I would like to see such building laws drawn up. In order to facilitate this I will make use of the data relating to the columns of the two collapsed structures, which I have mentioned, and with which you are familiar, and will show how proper ordinances can prevent similar faulty construction.

Some building ordinances speak of concrete only in a very general way; they specify a certain load "per square foot of concrete," which shall not be exceeded in the design, but make no mention of the proportions of the various substances that make up the aggregate and thus make it possible for the architect to specify 1:4:10 concrete in places where 1:2:4 or 1:3:5 would be the proper mixture to use. I have more than once heard contractors argue that in certain walls and piers a mixture of 1:4:10 would do, when I had specified the work to be made of 1:3:5 concrete. Moreover, the nature of the crushed stone and sand should be taken into consideration. The stone should be submitted to tests for compressive strength, so that the contractor may be sure that it does not weaken but rather strengthens the concrete. The best of all would be to have the contractor determine the voids in the crushed stone and in the mixture of crushed stone and sand, and thus to find the most favorable ratio of cement to stone and sand, as this varies with the nature of the aggregate. By these means the contractor may not only obtain a harder concrete, but in many cases considerably reduce the cost of it. The percentage of reinforcement should be specified for the various mixtures of concrete and for varying loads, so that it may not happen again that an architect tries to reinforce a 20-inch column in the basement of a five-story building by four ½-inch rods, that is to say, by less than ¼ per cent of reinforcement. The columns are naturally the points from whence the greatest disaster is to be expected, as their failure causes an entire portion of the structure to come down, while a weak girder or beam can only be the cause of the collapse of a floor panel. Therefore columns should be heavily reinforced and preferably only by reinforcement which gives ample warning of a coming disaster, as by crumbling and scaling off of the concrete on the outside of the column. Such reinforcement is spiral reinforcement of the Considere type or expanded metal cylinders. These should be used exclusively for columns, which have to sustain heavy loads, and bars of any description should be prohibited. For girders and beams, trussed bars should be preferred to single bars, which are simply connected by stirrups, as the former represent units which cannot be easily moved out of place in tamping the mortar into the forms.

The thickness of the wooden planks and wooden supports of the forms should be specified for each load, so that girders and beams be not deformed during the tamping of the concrete. In the construction of floors it should not be allowed to erect the woodwork for the next floor above it on the green floor. This method of building the floors imposes too much of a load on the fresh concrete. The forms for the floors should be supported independently of the floor underneath by inclined posts, so that the weight of the forms and floor shall rest upon the columns and girders, and not upon the floor below. Or in case the former method of construction is adopted, the centering should be removed only when the top floor or roof has set hard, and then the removal of the planks and supports should begin at the top and not at the bottom, so that a comparatively fresh third floor has not to sustain the load of three or four floors above it with all the woodwork between them.

The requirements of which I have spoken so far, dealt with the design of the structure or the method of erecting it. We now have to discuss such methods for testing concrete as might reasonably be forced upon the contractor in order to assure success. It is not at all sufficient to test the cement, crushed stone and sand. The contractor may have the best materials on the ground, that can be imagined for the purpose, and yet he may make them into a weak concrete and his work may result in failure notwithstanding skillful design and proper and sufficient reinforcement. Therefore I regard it as the most important

point in concrete construction, that every contractor, who undertakes to erect buildings more than one story high, should have a small shed on the grounds which is more or less equipped as a testing station according to the amount of work he undertakes.

The main equipment of such an experimental station should be a powerful hydraulic press which enables him to crush 6-inch concrete cubes. During the course of construction he should take a sample of the well-mixed concrete that goes into the construction work and should fill a mold with it at the time the concrete is being tamped into the forms. This should be done for every cubic yard of concrete that goes into the columns, girders, beams and floor slabs; it might be done less frequently with foundation work where larger amounts of concrete are involved. The molds should be set aside and should be numbered, so that for each test piece it is known with which part of a column or with which girder or beam it corresponds. Then before striking the forms the contractor should crush his test cubes and determine their resistance to compressive stress. This alone will tell him whether or not he can safely remove the woodwork. There should be several test cubes for every 5 or 10 feet of a column or girder, so that an average from 2 or 3 tests is obtained and that still some test pieces remain for future dates, if the strength is not found to be satisfactory, when being tested the first time, and if consequently the concrete work has to be allowed to harden for an additional week or two. Such tests would show the contractor at which part of his construction weak concrete has been used. He would have to give that special part of the building more time to harden or can remove it in time and replace it by better concrete, if he notices that the test cubes which he keeps do not increase in strength from week to week.

The figures which the contractor obtains from his test cubes submitted to compressive strength will enable him to calculate the load that a column is able to sustain. He knows by experience or from observations of competent experimenters how much he is allowed to add to the strength obtained by his tests for every per cent of reinforcement of a certain type which he has imbedded in the concrete.

If a few of our large cities would make a start and adopt such building ordinances as I have suggested, smaller towns would soon follow their example and it would be known among the building public, where ordinances exist which safeguard concrete construction and where not. Then every prospective owner of a building no matter in which State or town or country place he may be, will be in a position to stipulate in his contract with the engineering firm or contractor who attends to the designing and erecting of the building, that in every detail the design and erection of the structure shall conform to certain approved building ordinances.

In order to attain the desired results the co-operation of every one interested in concrete construction is necessary. All experimental stations equipped with the proper testing apparatus should offer their services for the sake of public welfare and every builder and contractor should in his own interest see to it that such laws and ordinances are drawn up and enforced. Only this will make concrete construction a safe enterprise and prevent it from falling into discredit.

The commissioners of buildings of our large cities would have to take the lead in this movement and to consult competent men on the subject, so that everything possible might be done to prevent failure in concrete construction by enforcing upon the designer and contractor certain standard rules and methods of testing. If all this has been attained, reinforced concrete construction will become the most widely used method of building. But, so far, concrete is the building material of the widest possibilities and yet the most unsafe to use.

ELEMENTS OF ELECTRICAL ENGINEERING.—II.

THE DYNAMO.

BY A. E. WATSON, E.E., PH.D., ASSISTANT PROFESSOR OF PHYSICS IN BROWN UNIVERSITY.

Continued from Supplement No. 1656, page 198.

One of the modifications of Faraday's apparatus for illustrating electromagnetic induction was to replace the primary coil by a bar magnet. If the function of this coil and the battery current was merely to set up a magnetic flux which should penetrate the other coil, a steel bar or rod, previously magnetized, would obviously accomplish the same results. Every time such a bar is thrust into the coil, the so-called "lines of force," bristling from the poles, will cut the convolutions of wire, and induce in them electromotive forces. If the coil is a simple one—wound all in the same direction—the electromotive force in each coil is always added to the rest, so that the sum total may be of considerable value; if one half of the coil is wound in one direction, the other half contrary-wise, the electromotive forces will annul each other. Such a winding would be called "non-inductive," and is often used in resistance coils, in order to eliminate unnecessary and undesirable interferences with other parts of the circuit.

Apparatus to illustrate this property of magnets to induce an electromotive force and a current in a closed circuit is shown in Fig. 4.

Whenever the magnet is thrust into the coil, the needle of the galvanometer moves in a certain direction; as soon as the magnet is held stationary, even within the coil, all induction ceases, and the needle comes to rest in its original position; but the act of drawing the magnet out again, also induces a current of the same strength as the first, but in the opposite direction; the north pole of the magnet induces a current in one direction, the south induces one in the opposite direction.

From this action a very broad corollary to Davy and Arago's discovery of the principle of electromagnetism can be drawn; for, whereas by the passage of current through a coil, a bar within will be magnetized, and its strength and polarity dependent upon the strength and direction of the current, so the thrusting of a magnet into a closed coil will produce currents of electricity, dependent for a part of its factors upon the strength and polarity of the bar. In other words, a current of electricity can produce a magnet, and a magnet can produce a current of electricity. No two physical forces can be conceived which have greater differences of manifestation and characteristics than electricity and magnetism, yet the one is always exchangeable for the other. In any assemblage of apparatus, where the electric and magnetic circuits are interlinked, the one cannot change without sympathetically affecting the other. Since a current is induced in the circuit every time the magnet is moved, the total effect may be increased to any desired degree by merely moving the bar, in and out, at a sufficiently rapid rate; and as the movement would be accomplished by purely mechanical means, the currents would be wholly independent of any batteries. The combination is really seen to be a simple dynamo for producing alternating currents. Such constructions have actually been built for experimental use, but reciprocating motions are avoided in machine construction as far as possible, and the same or better results are accomplished, with somewhat different arrangements of the constituent parts, by resorting to simple rotary motion.

Fig. 4.—Production of Electric Currents Without the Aid of a Battery.

By referring to Fig. 4, it will be at once recognized that it is equally allowable to let the magnet be the fixed part, and to slide the coil on and off the magnet; relative motion between the two being the only essential. In the actual construction of dynamos, either member may therefore be the revolving part; for direct current machinery it is more convenient to let the coils in which the currents are induced be movable, while for alternating current machines there are some advantages in rotating the field magnet. Detailed descriptions of machines embodying both principles of construction will be given in succeeding articles.

Fig. 5.—Clarke's Form of Magneto-Generator.

Early dynamos were rather small, probably weighing not more than 50 pounds, and were usually arranged to be driven by hand power. A typical form, made between 1840 and 1850, was known as Clarke's, and is shown in Fig. 5. It is seen to consist of horseshoe shaped permanent magnets and a pair of revolvable coils; the shaft passes through and is fastened to a flat iron bar to which two short iron rods are attached for holding the coils and continuing the magnetic path. The wire that connects the two coils takes an S shaped path in going from one to the other, while the two other ends are led to two semi-circular contacts called the "segments" of the "commutator"; two oppositely placed "brushes" of thin spring brass rest on these segments and serve to make the connection between the revolving coils and the fixed binding posts. A commutator is always needed if it is desired to have the currents unidirectional in the external circuit, therefore an explanation of the function of this accessory will at once be given.

Lines of force are conceived as emanating from a north pole and entering a south pole. As the coils rotate, the lines of force therefore enter first one of the iron cores, then the other; the effect is analogous to plunging first one pole then the other of the bar magnet of Fig. 4 into the coil; i. e., currents are induced in alternating directions. This result then, in a dynamo, is unavoidable, that when the conductors pass under the north pole, the electromotive force and current are induced in one direction, and under the south pole in the opposite direction; the natural condition of the currents is alternating, but a continuous external direction can be secured by allowing the brushes to exchange contact with the two segments during the interval between the dying out of the current in one direction and its starting in the other.

Simple alternating currents could be supplied from such a machine by merely substituting two complete and insulated rings in place of the two segments; but the early experimenters knew of no use for such currents, and considered that mechanically generated electricity would be no substitute for that produced by chemical action in a battery unless the direction of flow was always the same. Though alternating currents are now utilized for almost all long-distance work, it is probable that more than half of the total electrical energy generated for commercial or industrial purposes is of the continuous sort, and for some uses, notably those of electrochemical nature, this sort is imperative. In order to effect the proper commutation with this simple construction, the brushes should be just bridging across the gap between the two segments, when the revolving coils are midway between the two poles of the field magnet. Clarke's model was freely copied by builders of physical apparatus down

Fig. 6.—Wilde's Electromagnet Generator and Its Permanent Magnet Exciter.

to comparatively recent times; it has the mechanical defect in not having balanced tractive forces, and the direct pull of the magnets causes undue friction and heating on the shoulders of the shaft and bearings.

Shortly after Clarke's time, Werner Siemens, in Germany, made a considerable improvement in both mechanical and electrical respects, by fitting the permanent magnets with cast iron extensions, or "pole-pieces," having faces of about a third of a circle in extent, and by winding the revolving coil in the grooves of an iron shuttle that also had circular faces. Brass ends fitted to the shuttle gave means of attaching two short pieces of shafting to run in appropriate bearings. By this construction, the magnetic pull on the core was equal in every direction, hence free from the defect just mentioned; but further, the very short air gap and large effective area of polar surfaces so reduced the reluctance of the magnetic circuit as to provide a much more intense field than was attained in Clarke's type. At best, however, permanent magnets are rather weak and expensive, and have the further disqualification of not allowing variations in their strength—or rather, of their weakness—for the purposes of desired regulation of the current. Siemens, therefore, made the further practical improvement of using electro instead of permanent magnets for the field. Current to energize these was derived from a smaller machine with permanent magnets, arranged to be controlled by varying the speed, or by inserting resistances in the circuit. A classic model by Wilde of Manchester, England, showing the combination of the two types of field is shown in Fig. 6. This machine was by far the most powerful one of its time, and with it, iron rods one-quarter of an inch in diameter and a foot long were readily melted. This idea of using a separate machine, now designated as an "exciter," to energize the field of a larger one is the common practice with alternating current generators.

In 1856, Siemens made a most important discovery—that for direct current use, the separate machine, with permanent magnets, was not needed. He found that the field magnet windings could be inserted in the main circuit, and by rotating the shuttle in a particular direction, the electromagnet would secure its proper strength. This is now recognized as the principle of "self-excitation." It is dependent upon the fact that ordinary iron once magnetized retains a small or "residual" amount of magnetism—just enough to start a feeble current in the circuit; and this current, though feeble, immediately adds to the magnetism, and so by a process, sometimes perceptibly gradual, and under other conditions almost instantaneous, the full degree of magnetism is attained. Machines with this self-exciting property the inventor denoted as being "dynamo-electric"; in modern parlance, the word is abbreviated to "dynamo." That part of a dynamo in which the electromotive force is generated is now distinguished as the "armature"; but its iron core not only bridges the path across the poles of the field magnet, but also serves as a substantial means of holding the "winding"; the winding is, however, the essential part of an armature, for some—notably the Ferranti type—have been made without iron cores.

If either Clarke's or Siemens's machines are supplied with currents, they will run as motors, yet for many years the word dynamo was held as signifying a generator of electricity as distinguished from a motor, which absorbed or used electricity. Now, a generic sense attaches to the former, and it is considered as embracing both uses of the machines; thus, a book on "Dynamos" would properly treat of both generators and motors, and even of transformers—that a dynamo is a machine or device for transforming mechanical into electrical energy, or *vice versa*, or from electrical energy in one form or condition into some other form.

The field magnet wires of Siemens's dynamos were relatively large, in few layers, and therefore of low ohmic resistance; all the current from the armature was readily passed through them. Consequently the machines were "series" wound, for the magnet coils were merely connected in series with the rest of the circuit. Whether the current flows through these coils before going to the external circuit, or after, is immaterial, and ordinarily, it might be unknown which direction prevails.

An armature having only two segments in the commutator can at best supply pulsating instead of steady currents. Twice in each revolution the current is zero and twice a maximum; the successive impulses follow each other like a row of semicircles, all on one side of a straight line. By employing additional sets of coils and commutators in intermediate angular positions, as was done originally by Wheatstone and later modified by Brush, the abruptness of these half-waves is smoothed out into fairly small ripples. To make armatures that will supply currents approaching in uniformity those produced by chemical action, quite a different construction is needed. Pacinotti, in 1860, made a crude attempt in the right direction; but Gramme, in 1870, invented the armature that has made his name famous, and his "ring" as representing a distinctive type. In this an iron ring, or cylinder, is wound, in and out, all around the circumference with insulated copper coils; taps, or twisted ends, are left out at a large number of places for connecting to an equal number of commutator segments; there is no electrical break in the winding from beginning to end, for the end of one coil is merely the beginning of the next; it is a "closed" coil winding as distinguished from the early type, in which the two ends terminated abruptly in the two commutator segments. In the

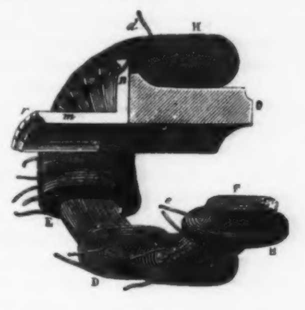


Fig. 7.—Early Construction of Gramme's Ring Armature.

closed circuit type, a start may be made at any point, and the convolutions followed until the identical starting point is again reached; in the other or "open" circuit type, such a tracing would lead to one of the segments, and the other could be reached only by following through the external circuit. Both sorts of windings are still used, the open type being principally exemplified in the Brush and Thomson-Houston arc lighting dynamos, but with preference, or rather the necessity, for the other type for most purposes. The reasons underlying the particular qualifications will be given in connection with descriptions of particular machines or systems.

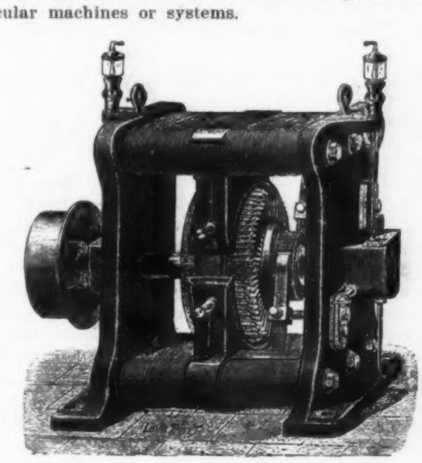


Fig. 8.—Gramme's Standard Dynamo.

A good idea of Gramme's early construction can be obtained by examining Fig. 7. It will be noticed that the iron core was not composed of a solid mass but of a coil of annealed wire, around which, with suitable provision for insulation, the copper coils were wound. A wooden ring was forced into the inside, effectually separating the commutator segments from that part of the winding, while a wooden sleeve, not shown, was used to separate the segments from the shaft. Since the field magnet had only two poles, two brushes were still all that were required, and these properly touched segments connecting with coils lying between the polar tips. Gramme's machines ran very quietly, with remarkable freedom from heating and sparking—conditions so prominent in previous constructions as to render their continuous operation impossible. The production of the Gramme dynamo marks the beginning of commercial electric lighting.

The source of the great heating in a solid armature core is easily explained. The principle of electromagnetic induction is broad, and if a cause exists for producing a current in one conductor, it will surely produce a current in any other. Iron is a conductor of electricity, and in the armature its relatively large mass may more than offset the higher conductivity of the copper. Therefore the cause that would induce a useful and desired current in the copper circuit, might induce a greater and useless, or even disastrous, current in the iron core. The remedy is simple and effective, and consists in subdividing the iron core by use of a mass of iron wire, or sheet iron, instead of the single mass of solid iron; by insulating these separate wires or sheets from each other, the paths of the "eddy" currents are made very short; indeed, discontinuous. Gramme made the first commercial dynamos, but he did not have the means of providing sheet iron of the right form, so he resorted to iron wire cores; by varnishing the wire before winding it into the form of a ring, he prevented the electrical connection of one wire with the next; but he also, thereby, introduced an undesirable magnetic reluctance; sheet iron disks, such as are now universal, are readily separated from each other by use of paint or tissue paper, but this "lamination" in no way interferes with the magnetic circuit. Electric currents are desired in the wires that go perpendicular to the plane of the sheets, but the magnetic flux passes edgewise in the sheets unconcerned by the subdivisions.

Gramme's first machines were small laboratory models, with permanent field magnets; but he soon made larger sizes, with flat or round core electromagnets. Fig. 8 shows a standard form for arc lighting, such as was first exhibited in Philadelphia in 1876 and in Paris in 1881. Its entire construction is still distinctively known as the Gramme type; with various modifications it has been largely copied by other builders, but in this country its very counterpart was manufactured for many years by the Fort Wayne Electric Company.

A peculiar property of this type of armature is that it is not limited to use in a two-pole field magnet; without any change whatever in the winding, it will operate under the influence of four, six, or any desired number of poles. Brushes must, however, be applied to as many different parts of the commutator as there are poles, alternate ones being connected together to form one set, the rest forming the other. It was a notable event though somewhat premature, when in the early '80's Gramme produced a machine with twelve poles. With a given armature rotated in a field magnet of successively increasing number of poles, the electromotive force will be less, and the current more, but the capacity in watts will be the same. Current is assumed as starting at a negative brush, and pursuing its course through whatever paths are offered, and emerging at a positive brush; the electromotive force between the brushes will be that generated in the total number of conductors that are in series; with such an armature, a two-pole field requires brushes on opposite segments, the current divides but once, and one-half the total number of conductors are in series; the number of amperes is determined by the carrying capacity of two wires in parallel; a four-pole field magnet would require brushes at four equidistant parts of the commutator—two positive and two negative—allowing four wires in parallel for conveying the current; but from one brush to the next, only one-quarter of the total number of conductors would be in series. Such a condition would therefore allow for twice as many amperes, but only half as many volts as in the two-pole case. With six poles, three times as much current and one-third as many volts would result. Dynamos for high potentials, as for operating a large number of arc lamps in series, would therefore be usually constructed with only two poles, or sets of poles, while machines for plating purposes, even though of small size, might well have multipolar fields. Very large dynamos for standard 500-volt use require numerous poles; or within the limits of convenient winding, the potential would be too high, and the current capacity too low.

In a Gramme armature, the coils can be well insulated, and have a large surface exposed to the air for radiating the heat inevitably generated in the copper; but the winding is tedious and expensive, and, except

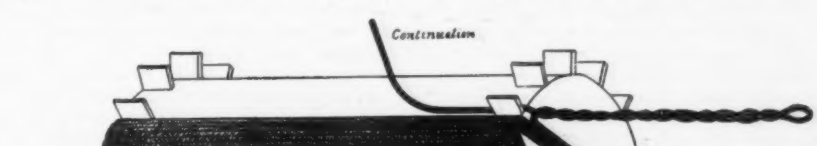


Fig. 9.—First Coil of a Siemens Drum Armature, Adapted for Two-pole Field Magnet.

for the one reservation of series arc lighting, has been supplanted by the Siemens "drum" type. This, too, is a closed circuit winding, but the wires do not pass through the interior of the core; they are fixed entirely on the outside of the cylinder, like the tightening ropes of a drum. Small armatures may well let the sheet iron extend quite to the shaft; larger ones would use ring cores, as if a Gramme winding was intended; but in consequence of the wires remaining entirely on the outer surface, the winding would really be of the drum sort.

Any one coil of a drum armature for a two-pole field magnet occupies any assignable portion of the circumference of the core, and an equally wide portion on the opposite side; the wires therefore straddle the shaft, and as the winding progresses, there results a considerable accumulation at the ends of the core. A clear idea is given of the appearance of the first coil of such a winding in Fig. 9. Like the ring winding, it is seen that the end of one coil is also the beginning of the next, and in the particular case shown it is not necessary to cut the wire until the last coil is on. Though a coil occupies two spaces, nearly or directly opposite to each other, the loop for the commutator connection is necessarily adjacent to one of these spaces only; therefore when the entire circumference has been once entirely covered, loops are provided for only one-half of the commutator segments, and to provide for the other half the winding must be continued on top of the first part until a second entire course is completed, when the beginning and end of the wire can be twisted together to form a final loop. When attached to the commutator, superfluous ends are cut off. Since the armature is of the closed circuit type, it has the same number of paths for the current as the ring type, but the winding consists of definite halves, between which the whole difference of potential is constantly exerted. Even though mica and other good insulators be used between these halves, the winding cannot safely be used for such high potentials as the ring, for in the latter the coils which are at highly different potentials are far apart, and have the benefit of the accumulated insulation. The drum type is largely limited to 500-volt direct-current machinery, or a maximum of 2,000 volts in alternators, while ring armatures for direct current arc lighting are regularly wound for 6,000 to 10,000 volts. Other qualifications of the two types involve principles of inherent regulation, due to the presence or absence of self-induction, and will be explained more in detail in connection with actual dynamo machines. In general, aside from matter of first cost and effectiveness of insulation, the ring armature is preferred for constant current use, the drum for constant potential. For purposes of illustration, it is a little unfortunate that diagrammatic figures ordinarily represent ring windings; drum windings would usually be found on the actual machines, and the student will have to make the transfer, mentally, from the more easily represented ring to the more readily wound drum.

A second essential difference between the two types of windings is that a drum armature must be wound for a certain predetermined number of field poles, and that when once wound for such a field, it will not operate in a field of any other number of poles. A given conductor must pass along under one pole and then return under the next pole; in a two-pole field this condition is secured by winding as shown in Fig. 9, but if the field has four poles, the conductor would need to return along a line 90 deg. instead of 180 deg. from the start; that is, the spacing of the coils, or technically, the "pitch," must conform to the location of the poles. The actual process of winding by hand a drum armature for more than two poles is very awkward and is not often attempted; the invention of the modern "form-wound" coils of just the right shape was fortuitous and effective. They admit careful insulation and a perfect electrical and mechanical balance. Particular attention will be devoted to machines with this type of coils in the fifth article.

Early forms of field magnets were not very economical; the paths for the lines of force were long, of meager cross section, with spaces for wire thin and wide. Relatively long lengths of wire were therefore required, without thereby embracing much iron. With a given length of wire, the maximum area will be inclosed if the coils are circular; square is the next best shape. Round spools are the easiest to wind, and if the cores are of solid iron, such may always be used; but if the cores are built up of sheet iron—"laminated" —the spools will necessarily be square or rectangular.

Magneto generators are now scarcely used for any other purpose than to operate telephone call bells, "series," "shunt," "compound" and "separate" excitation of electromagnets being the four practical methods. Their meaning and application can best be considered as they were developed in connection with the demands of actual engineering problems.

The third article will describe dynamos adapted for series arc lighting with especial reference to the unique and successful work of Brush and Thomson.

(To be continued.)

THE DESIGN OF INDUCTION COILS.*

PRACTICAL HINTS FOR THE AMATEUR AND THE MANUFACTURER.

BY WILLIAM O. EDDY AND MELVILLE EASTHAM.

Concluded from Supplement No. 1657, page 214.

THE INSULATION AND THE INSULATING TUBE.

THE insulating tube is placed over the primary winding to insulate it from the secondary, and it should be as thin as its insulating qualities will permit so that the secondary may be placed as near to the core as possible. The material of which this tube is made should, of course, be a good insulator, but its specific resistance is of less importance (provided its dielectric strength is great) than the specific dielectric capacity, K; since the current passing between secondary and primary, due to the capacity effect, will be great in a high-potential coil as compared with leakage current.

The thickness of the tube need be only enough to withstand three-fourths of the secondary voltage, since for X-ray or wireless work there is almost never an absolute ground at one secondary terminal, and, even though the coil should be operated while grounded, the capacity of the coil is so much increased under the conditions that the current required to charge it will materially lower the potential.

When the coil is to be worked on open circuit or with a resistance the potential at the center of the coil is practically zero; therefore, we may apply Siemens's idea of decreasing the thickness of the tube at the place where the lines of force are strongest and the secondary turns are most effective, as shown in Fig. 1. This, although it adds complication, is often an advantageous practice in large coils.

The substances that may be used for this tube are glass, built-up mica, gutta percha, and hard rubber. Of these glass is easily broken and has perhaps the highest specific dielectric capacity combined with a comparatively low dielectric strength. Micanite has a high rupturing voltage, but also a high capacity, while both gutta percha and rubber have low capacity to recommend them.

The importance of the specific dielectric capacity (K) may perhaps be more evident by applying the equation $Q = CV$, where Q is the quantity of electricity that must be drawn from the secondary to charge the coil at each impulse before useful current can be drawn from it. C is the capacity of the coil (considering the primary and secondary windings to be the two conducting plates of a condenser) and is directly proportional to K, while from the formula it is seen that the quantity of electricity required increases directly as the voltage of the secondary winding. With a high speed interrupter and a large high potential coil this factor is of great importance, and upon the capacity and the insulating powers of the tube will depend very largely the maximum voltage that the coil will withstand and energy it will deliver.

We will mention here a well-known experiment performed with high-frequency currents of placing two pieces of plate glass, parallel to each other and separated by an air space of an inch or more, while the two terminals of a high-frequency machine are connected to their outside faces. The high-frequency spark now jumps across the air space between the glass plates without puncturing the glass. The explanation of this phenomenon is that because of the high K of the glass the current is transmitted through it as a condenser would allow it to pass, while air having a value for K of only unity must allow this current to pass in the form of an actual spark. A comparatively thick sheet of any insulator, possessing a low K, placed between these glass plates may be ruptured in the same way, without injuring the glass, by a current of high enough frequency. By applying this principle we see the advantage of having K nearly uniform throughout the insulation of a coil. With a high speed interrupter and a heavy current little sparks may be seen inside of the insulating tube jumping into the primary winding, and for this reason a very large coil should have this small air space filled with some kind of insulating compound.

In connection with the insulating tube will be discussed the insulation of the secondary, which is required between and outside of the sections or "pies" of the secondary winding. For the insulation between the sections a solid insulator, or paper impregnated with an insulating compound, should be used. Paper alone is not the best insulator, but when impregnated the combination surpasses in insulating qualities either substance by itself. This method furnishes also a most convenient means of supporting the sections of winding a uniform distance from each other. The outside insulation is required for the protection of the secondary winding, and because many coils are worked with a longer spark length than the distance between the two extreme end sections.

If the secondary winding is left open much energy is wasted by the little streamers that brush out into the air, and this loss is greater the higher the potential. Ozone is also generated under these conditions, which deteriorates the insulation between the secondary turns, and eventually causes a burn-out. The forming of these streamers is best prevented by having the coil immersed in oil; but in most cases the conditions under which the coil is used are such that the sloppiness of oil insulation is a prohibitive disadvantage. Vaseline and other semi-liquid insulators are popular in Europe, while American manufacturers are partial to solid insulators, such as paraffin or a combination of resin with beeswax or other substances. Paraffin alone, though often recommended, is not the best insulator for this purpose.

It is of course of vital import that whatever insulator is chosen should have a high dielectric strength, but K is another factor that should influence the selection. We have shown that an increase in the value of K for the insulating tube will make a difference in the amount of current it will take to charge the coil, and the capacity between the different sections of the secondary adds materially to the total capacity of the coil, and the best condition would be, as already suggested, for K to have the same value in each case.

It is most important that all moisture should be driven out of the winding by heating or otherwise before the coil is finally insulated, and Flemming suggests that where oil can be used it should have a higher specific gravity than water, especially if it is to be used in a damp place.

In order to make sure that all the air is driven out, the vacuum system is to be most highly recommended; and for this purpose most of the largest manufacturers have installed vacuum impregnating apparatus.

The method of putting the coil in a box and imbedding it entirely in solid insulation is not to be recommended because of the increased weight and the difficulty of getting at the winding should any repairs become necessary.

THE SECONDARY.

The number of turns and size of wire of the secondary winding will depend upon the spark length desired and the purpose for which the coil is to be used. The theoretical formulæ for the maximum secondary voltage, which determines the spark length, are based on so many conditions and approximations not met in actual practice that their application to the specific design of a coil is of little value as compared with practical experience. As we have already mentioned, the "kick-back" voltage of the primary in coils, as usually constructed, has been found to be about twenty times the voltage applied across the terminals, and the maximum voltage of the secondary has a proportionality with the primary "kick-back," viz., the ratio of the number of turns in the two windings. Moreover, the primary "kick-back" and the primary current are proportional up to a certain point. This point is the point of saturation on the magnetization curve and is determined by the amount of iron in the core. We can now appreciate the contention that the rating of a coil should include the amount of current to be used and can see that, for instance, a nine-inch coil design for three amperes will not be the best where twenty amperes are to be used.

The secondary voltage is directly proportional to the number of turns in the secondary; this is the most important consideration. There should not be a larger number of turns than is required for the spark length in order that the secondary may be kept small, cheap and effective. Of course the longer the spark length, the smaller will be the value of the secondary current for a given interrupter and a given amount of primary current.

The number of turns in the standard 12-inch coils now on the market ranges from 50,000 to 80,000, although a spark of over three feet has been obtained with 85,000 turns.

The size of wire is somewhat of a compromise and on this size will depend the strength of the secondary current and the volume of the spark. The small wire

* From the Electrical World and Engineer.

has a greater resistance per unit of length, but a shorter length will be required, as it can be more compactly wound. On the other hand, the resistance decreases inversely as the square of the diameter, and a large wire must be used where much energy is needed. Even when merely a certain spark length is required a size smaller than No. 36 is not advisable, and for the maximum size the compromise might be drawn at No. 32, except in the case of a coil built for some special purpose.

We now come to the dimensions of the secondary. The cubic space that this will take up has been pretty well fixed by determining the size of wire and the number of turns, but these and the size of the core could not be definitely designed without reference to the form the secondary will assume; a cut-and-try method being employed for this determination. Perhaps a good proportion for the secondary length would be the same as the distance between the terminals of the secondary, but this may not be practicable in small coils where the drop of potential per turn of primary is less owing to the small amount of iron. Rochefordt and Weidts advise a secondary one-fourth the length of the primary, others one-third the primary length, and still others extend it nearly the full distance.

As for the outside diameter of the coil a good ratio for the secondary is three times the core diameter; but this must depend on other considerations.

The secondary may be built long and slender or short with a correspondingly larger diameter, but the latter form will require a longer length of secondary wire. By referring again to Fig. 1 it is seen that the field is strongest at the middle of the core and decreases toward either end. It also decreases as we move away from the core at right angles to its axis. If space and current were of no value use could be made of a much larger amount of iron, only a small section need be employed in the center of this intense field for a comparatively small secondary winding, which would then be most effective and give the maximum voltage and power per turn of winding.

Because of the disposition of the lines of force around the core, the diameter of the secondary is often decreased toward the ends as shown. This is accomplished in the actual coils by a series of steps, which of course means expense in winding and assembling.

Many makers have wound the outside sections with heavier wire than the inside, not appreciating the fact that, although the potential is greater, the current is the same throughout the whole winding. This is analogous to putting heavier links at the ends of a chain than in the middle. It is a little odd, however, that this old custom should happen to be a good thing in wireless telegraphy where these few end turns may have to withstand high frequency currents. Where separate inductance coils are not used for the purpose, these secondary turns have a big choking effect on high-frequency currents, and they should be especially well insulated from each other.

When there is capacity across the secondary the insulation is overworked, and with a high-speed interrupter the natural period of the circuit may be approached and unwelcome oscillations may be set up in the secondary.

The secondaries of two coils are sometimes run in series to obtain a high potential, but it can be readily demonstrated that the capacity of the two coils as a condenser is greater than would be that of a single coil of the same spark length.

Besides a high potential, a large quantity of current is required in wireless telegraphy and a properly designed 12-inch coil having the same outside dimensions as usually given to a 16-inch coil will handle more energy and give better results than would the ordinary 16-inch or 12-inch coil. Flemming speaks of a 10-inch coil giving less than a quarter inch spark with a capacity of one-eighteenth of a microfarad across the terminals.

Another phase of the importance of the secondary resistance, about which we have said so much, may perhaps be made more apparent by a few statements regarding the "time constant" of a condenser. It is important in wireless work to charge the condensers in the shortest possible time. The product of the condenser capacity in microfarads and the resistance in megohms through which it is charged is known as the time constant; the resistance of the secondary of the coil counting into this resistance. A condenser will be practically charged to the applied voltage at the end of a period which is equal to about ten multiplied by the time constant. By way of illustration Flemming calculates that for a capacity of one microfarad charged through a resistance of one megohm by an applied e.m.f. of 100 volts the condenser would be charged to only 63 volts at the end of a second and to 86 volts at the end of two seconds. For a more usual case, a capacity of 1-100 microfarad would be practically completely charged through a resistance of 10,000 ohms (1-100 megohm) after the voltage had been applied for 1-1,000 second, and what this condition would mean with an electrolytic interrupter can easily be appreciated.

Let us now consider the various methods of winding the secondary.

One way is to wind the wire in layers, the insulation being increased as the difference of potential becomes greater between the layers, and numerous large coils have been wound in this way. The accepted practice, however, is to make this winding in sections or "pies" and then connect and assemble them on the core. The thickness or width of these disks may be an inch or more or the diameter of a single wire; the outside diameter determining the outside dimension of the coil and the inside diameter being large enough to allow it to slip on over the insulating tube. The thicker the pies, the greater must be the insulation between them; the usual thickness is from 1/16 to ¼ inch, ⅛ being of a good size for coils from 6 to 16 inches in spark length.

Leslie Miller has invented a machine for winding these in a spiral the thickness of the wire, the first layer being wound from the outside toward the center and the next from the inside outward in the opposite direction and so on, using a single sheet of impregnated paper for insulation between them and making the whole secondary one continuous wire without the necessity of making any soldered connections.

Some makers use thin sections insulated from each other with mica and without other insulation, the windings being open to the air.

There are two ways of connecting the sections together: Either from the inside of the first to the outside of the second and from the inside of this to the outside of the next; or, by connecting the two insides and the two outsides of succeeding sections. These two methods are shown in the sketches of Figs. 5 and 6.

Where the second method is adopted the coils may be wound in pairs, so that there will be no soldered connection at the inside. This is done by having the winding wire on two spools and revolving one of these with the first coil till it is finished, and then using this second spool for the other coil of the pair.

We see by an inspection of Fig. 6 that there is alternately between the insides and outsides of the sections, twice the difference of potential of a single section, while Fig. 5 shows that there is across any part of two consecutive sections never a greater difference of potential than that generated by a single one of them. Unfortunately this connection cannot be run down on a slant, but because of constructional difficulties it must be run as shown in the last sections, passing down midway between the two, and here we have at both the inside and outside positions of this wire the full potential difference of a single coil with only one-half the thickness of insulation between them. This makes the danger of puncture at these two points as great as in the method shown in Fig. 6, but here the danger is at two single points instead of two lines the full length of the inner or outer circumference of these sections. Unless the coil is to be immersed in oil the insulation between sections should extend beyond the winding in order to prevent the spark from jumping between the sections over the surface of the insulation. This makes the path for the spark over this outside surface greater, but we do not want to waste space in this way at the inside of the sections where there is great danger of sparking along the surface of the insulating tube. We can, however, increase this distance by winding the edges of these coils on a slant as shown.

THE CONDENSER.

This discussion would not be complete without some attention being given to the condenser that bridges the interrupter in the primary circuit; the understanding of which is none too clear. There is an old idea that this condenser absorbs surplus electricity at "make," but a glance at the diagram of Fig. 2 will show that the condenser is short-circuited at this time and can play no part unless it be to spark across the gap, just before contact is made, in giving up a charge left over from the "break." The function of the condenser is to give a more rapid speed of break by preventing or minimizing the arc that would otherwise be drawn between the contacts. There is a best capacity for this condenser, as will be seen later.

The optimum capacity, according to Ives, for a given condition of working is that capacity that will give the longest secondary spark and is the least that will cut down sparking at the interrupter near zero. The longest spark is not obtained at the condition of least sparking at the break. For the latter condition we must add more capacity, and when the capacity is greater than the optimum Mizuno has shown that the spark length of the coil is decreased.

The current in the primary circuit which is broken by the interrupter charges the condenser at break, which, according to Walter, as shown in the last curve of Fig. 3, causes across the gap an oscillatory discharge as the contacts separate. His theory is that the higher this rate of oscillation the better, and the smaller the capacity the faster will be this rate, but it requires a capacity at least as large as the optimum to take care of the arc and a larger capacity than this would only use up more current to charge it. Possibly, as Flemming suggests, the current oscillating through the primary may hasten the demagnetization of the core.

Since it is advantageous to build a coil that will require the least capacity, let us see upon what factors the optimum capacity will depend. Lord Rayleigh has found that by increasing the speed of break, the amount of capacity required is lessened, and when the circuit was broken by a bullet from a rifle, the longest spark length could be obtained with no condenser at all.

The capacity is also found to vary directly as the inductance of the primary, up to a certain point.

Ives has found that the resistance of the circuit, *a b c d*, of Fig. 2 should be as small as possible; *b* showing the break and *c* the condenser. The capacity increases with the primary current in a ratio greater than the square of the current and less than the cube; this ratio being nearer the square the smaller the resistance of the condenser and interrupter circuits; therefore we see the advantage of keeping the resistance of these leads and connections as low as possible.

Some types of interrupters will work as well without a large capacity, and we will see if we can find a reason for this. The Wehnelt interrupter has very little arcing on small currents and it is a very rapid form of interrupter, and with its high rate of interruption it has also a high speed of break. Moreover it is known that the platinum point and the solution form an electrolytic condenser across the break of comparatively large capacity. We have already called attention to the fact that the secondary spark at make with this interrupter is sometimes very great, but this type possesses a great advantage in the amount of current that it can handle and because it can be run on a commercial lighting circuit.

The mercury interrupter has an extremely low resistance, and besides this, mercury is more or less a non-arcing metal.

In all cases the capacity should be made variable, unless, as seldom happens, the coil is to be run on a constant amount of current under unvarying conditions.

In subsequent articles the practical design and construction of several sizes of coils will be described.

PEARL INDUSTRY IN THE UNITED STATES.*

Each year there is an unrecorded production of pearls from fresh-water mussels of many of the rivers of the United States. The principal yield comes from the Mississippi Valley region, where beds of pearl-bearing mussels are found in many of the tributary rivers. Along the Atlantic Coast States pearls have been found from Maine to Florida, and in the Gulf States from Florida to Texas.

The season for gathering pearls and mussels is from May to November, when buyers and dealers travel from one locality to another where there are pearl fisheries. Often the mussels are gathered in large quantities and opened simply in search of pearls, and then thrown away with no thought of their value for manufacturing pearl buttons. In other cases the shells are saved for this purpose, but much useful material is wasted at the button factories. With the reckless destruction of millions of mussel shells for pearls and button manufacturing, the beds of these shells are being rapidly depleted, and unless some steps are taken for their preservation it will not be long before the deposits will be exhausted. Laws passed to prohibit the gathering of shells and pearls on certain portions of the rivers for a period of years after once being fished over, would give the mussel beds a chance to restock themselves, and thus a permanent industry would be established instead of one rapidly working out its own destruction.

Many pearls are desirable for their even qualities and the ease with which they can be matched, while American pearls exhibit the greatest number of variations in color and tint, and it is difficult to match exactly a number of them for necklaces and other jewelry. On the other hand, the exquisite coloring and the fine luster of our pearls more than offset the disadvantages due to such irregularities, and make them much desired in the gem market. The pearl industry is carried on in such a way that it is not possible to collect statistics showing the production. Buyers and dealers, not only from New York and other eastern cities, but even from Paris, visit the Mississippi region in the pearl-gathering season, travel from point to point, and at the end of the season return to their places of business. Many small dealers sell to larger ones on the spot; others send their product off to be marketed. In many cases parcels of pearls change hands two or three times before appearing in the gem markets. Pearls amounting to many thousands of dollars are exported annually, which apparently have not been reported to the Bureau of Statistics of the Department of Commerce and Labor.

* Abstracted from a bulletin issued by the United States Department of the Interior.

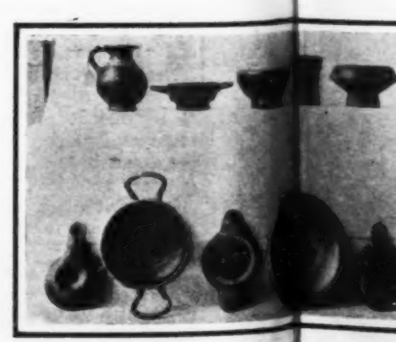
PUNIC STATUETTES FROM CARTHAGE.

PUNIC ORNAMENTS, ETC., FROM CARTHAGE.

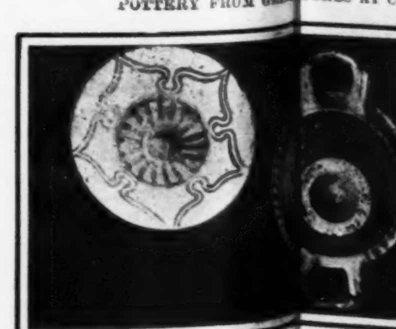
The countries of Northern Africa, bordering the Mediterranean, fell under Roman domination at an early date; and being separated only by the sea from Italy, were extensively colonized. The cities which the Romans established there were successively conquered or ruled by Byzantines, Vandals, Arabs, and Turks, and at times have been open to the pillage of the whole of Europe. In the middle ages the Venetians despoiled them of marble pillars, carved stones, or anything which would add to the beauty of the buildings of their city. In spite of these disasters the trace of the Roman rule is still apparent. In recent years, since Tunis and Algeria came under the influence of France, French archæologists have done much excavating on the site of old cities, with encouraging results. In Carthage itself many traces of the Punic, pre-Roman period have been found; and evidences of the influence of Greece. Much of the recent work has been done at Timgad, a Tunisian city which has been preserved by being gradually silted up with desert sands. These

A ROOM IN THE BARDO MUSEUM,

A STREET IN TIMGAD. THIS ILLUSTRATION GIVES A GOOD IDEA OF THE DEVASTATION WORKED BY THE LATER RACES, WHO QUARRIED STONE FROM THE ROMAN BUILDINGS.



POTTERY FROM GREEK TOMBS AT C



POTTERY FROM TOMBS, CARTH

ROMAN CITIES OF NORTHE

A FUNERAL VASE, CARTHAGE.

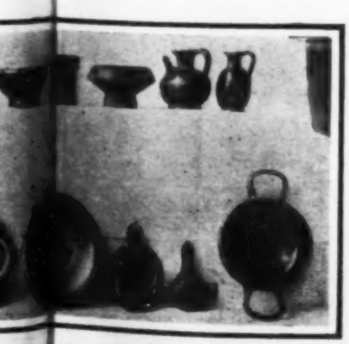
FRAGMENTS OF PUNIC ARCHITECTURE, CARTHAGE.

THE B DO MUSEUM, TUNIS.

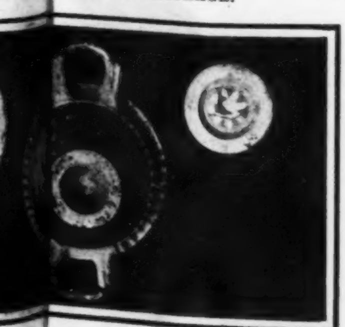
drifting sands have been removed from a large part of the city, and though the buildings have been found hacked to pieces by the races following the Romans, the plan of the city itself is preserved. An examination of this has shown that Timgad was built on a definite plan. The streets intersect at right angles, as in a modern American city, and a space usually separated the houses.

The Romans were wonderful engineers. The roads and aqueducts which they built are still in use in some European countries. Near Timgad an aqueduct still stands, having been restored by the Arabs after they had let it fall into decay.

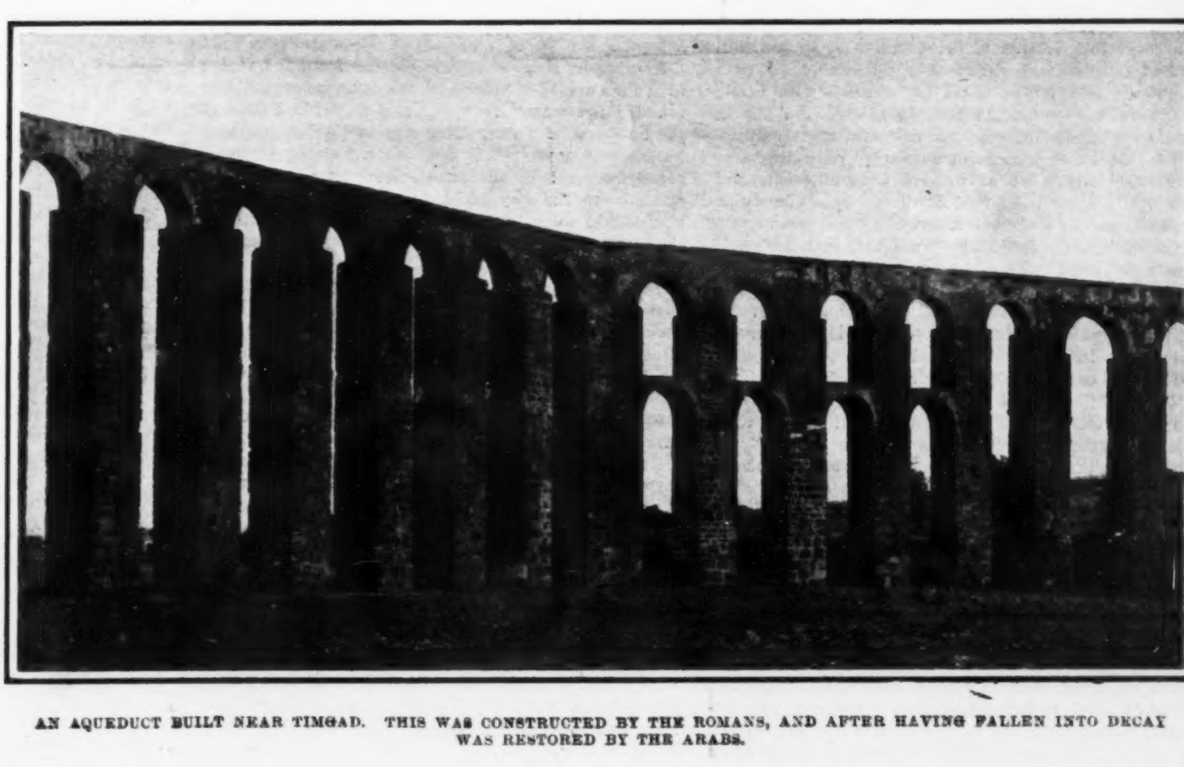
Museums have been opened in Carthage and Tunis for the preservation of the smaller objects found in excavations. The one in Tunis, of which a view of one of the rooms is given, was originally a palace of the Bey of the country.



M GREEK TOMBS AT CARTHAGE.



FROM TOMBS, CARTHAGE.



AN AQUEDUCT BUILT NEAR TIMGAD. THIS WAS CONSTRUCTED BY THE ROMANS, AND AFTER HAVING FALLEN INTO DECAY WAS RESTORED BY THE ARABS.

S OF NORTHERN AFRICA.

ROMAN CITIES OF NORTHERN AFRICA.

RELICS OF AN ANCIENT CIVILIZATION.

BY THE PARIS CORRESPONDENT OF THE SCIENTIFIC AMERICAN.

During recent years parts of northern Africa, bordering the Mediterranean, have proved a rich mine for archæologists. Separated only by the sea from Italy, the shores of Tunis and Algeria at an early date fell under Roman domination. Wealthy cities sprang up at important points, and retained their civic life for centuries. After hundreds of years of barbarous rule these coast countries have come under the influence of France, and French archæologists have done notable work in excavating and protecting their remains of ancient civilization. Many objects of interest are preserved in museums at Tunis and Carthage. Some of these are illustrated here; but it is not as a mere mine of "curios" these shores are excavated. From this point of view Tunis is much inferior to Egypt. In the latter country several causes, such as the continuity of the priestly rule for centuries, the reverence to the dead, and the custom of endeavoring to render things imperishable, have combined to leave very full records for the present day. In Tunis, on the other hand, a change of rule was frequent; and with the changes cities were sacked, either swiftly by a mob of soldiery, or more slowly though none the less surely by the inhabitants or others, who demolished old buildings to provide materials for new ones.

Within the last few years the French have done much work at Timgad, a Tunisian city, with encouraging results. The city has suffered from the plundering of two classes of builders, but still retains the unmistakable mark of its Roman origin. The more ambitious of the spoilers carried away marble pillars and carved stonework, appreciating their value. Thus, medieval Venice was largely built and decorated with the plunder of ancient cities. The second class of spoilers merely took the most accessible stones with which to build their own huts or sheds in the neighborhood. They had a habit of picking out the courses of dressed stone to a convenient height from the ground—usually not more than six or eight feet—and leaving an undermined, topheavy superstructure, which sooner or later fell to the ground.

Timgad is unique of its kind, and nowhere else do we find a buried city which bears such a close analogy to Pompeii. It is a city of large extent, buried by the sands in the course of time, and a large part of it is now uncovered, showing the principal streets, its forum, temples, public baths, and dwelling houses, over a wide tract. We have previously given some general views of this city and at present we refer principally to the more recent excavations.

One of the largest of the private dwellings is known as the House of the Garden. Its principal entry gives access to a vestibule, and from this the atrium opens opposite the entrance, and a room on either side. The latter rooms are situated so as to face upon the portico which passes along the main street in front of the house. In the central part of the house is an interior court which has a colonnade around the four sides. What is somewhat peculiar is that the court is partly surrounded by a raised artificial garden. This is formed by an inclosure of stone so as to hold the earth. A series of upright flags was placed around the court just outside of the columns of the portico, and at some distance in front was a second series to allow the intervening space to be filled with earth, and here were no doubt planted flowers and plants. The outer facing of stone is not a straight surface, but is formed of a series of outwardly projecting arcs like bay-windows, so as to give a more ornamental effect. Built with the wall of the garden beds was a series of square stone columns which rose to a certain height, and were topped with ornaments such as double heads or tragic masks. In the court is a well about ten feet deep. At the top it had a well-head of stone, like those which are to be seen at Pompeii. In one of the rooms opening from the atrium is found a mosaic floor in white, blue and yellow pieces. The *tablinum* has a larger and better executed mosaic floor, showing a flower and leaf pattern of good execution. As the present house lies in that part of the town which is reserved for public buildings, it is thought that it was the dwelling of a magistrate or other official person.

In Timgad the houses are in a much damaged condition, and are rarely to be found intact, as occurs in Pompeii. After suffering much from plunder, the city was finally abandoned and in the course of ages became filled up by the drifting sands. In carrying out the excavations a great deal of work had to be done in consolidating and partly restoring the walls of the houses. This was done for a few feet in height and then the upper surface of the wall was flattened off so as to give a finished surface. The city was certainly inhabited after its destruction by the Berbers in 535 A. D., if not by the Byzantines or the Imperial soldiers, at least by the natives or the degenerate descendants of the Romans, who modified the arrangement of the houses, and used material which they took from the older constructions. It may be noted that at Timgad the houses, at least the larger ones, were spaced apart and not built together as we find at Pompeii. Most of the streets lying within the city walls were placed at right angles and at regular distances upon a very methodical plan and in this respect it resembles a modern town. This is owing to the fact that Timgad was built according to a preconceived idea and at one time. Under the streets, most of which are paved with large flag stones, are found sewers of great size and in some of them a man can walk upright.

During the Byzantine period a number of basilica were erected, and at least seven of these ruins are found in the city. One of the largest is the church which is illustrated here, which covers a large area of ground. The basilica included a court which communicated with the street, and also several annexed buildings. The nave was about forty feet in length and a series of columns separate it from the side aisles. Some of the Roman ruins furnished the columns, as often happened in like cases. The altar table was formed of red marble. The paving of the main court was in large flagstones. Behind the apse were found a number of sarcophagi of wealthy persons.

One of these is formed from a single stone and is decorated with a molding; the others are built of a rough masonry. A gate leads from the church to a narrow gallery surrounding a court built after the manner of an atrium whose four porticos are upheld by columns. This atrium was used in the present construction as the baptistry, and seems to have belonged to a still more ancient basilica. In the center of the court is the compluvium, in the form of a circular basin provided with three steps leading to it, and four light columns upheld a roof over the basin. Adjoining the basilica is a very large and handsome dwelling, and it is somewhat built into the church. Much of its material was used in the construction of the latter. The atrium of the house served as a burial place connected with the church, and here we find a number of sarcophagi ornamented with Christian emblems.

No less than six public baths, some of considerable size, have been found up to the present. The baths which lie in the northern part are the largest, and they are situated outside of Trajan's wall. Here the ruins of the building have the walls no less than twenty feet in height in places, and the structure measures 250 by 210 feet. Four main doors open into it, and in the center of the building are the main halls, three in number, around which are ranged all the other parts of the baths. These large halls were used as promenades or for games or gymnastic exercises. One of these halls is 80 by 60 feet and was originally decorated in a very handsome manner. There are a great number of rooms for hot and cold baths, laid out upon the usual plan of the Roman baths, such as are found in Pompeii.

A great number of objects coming from the region of Tunis are now placed in the museum which was founded not many years ago at the Bardo Palace in the outskirts of Tunis. This was originally the Beys' Palace, and even yet it contains a number of handsomely decorated and furnished rooms which belong officially to the Bey Mohammed-es-Sadok, but as he now inhabits a villa at Marsa, on the site of Carthage, the Bardo Palace is scarcely used except on state occasions. A number of rooms have been occupied by the new museum. There is now a large museum on the site of Carthage itself in which are placed all the finds coming from the Rev. P. Delattre's excavations. This latter collection is a much larger one than that at Tunis, for objects are being added to it continually.

One of our illustrations shows a view in one of the principal rooms of the Bardo museum, and the objects, consisting mainly of mosaics and statues, are tastefully arranged. Nearly the whole floor is covered by a great mosaic which is one of the largest discovered. It was found at Sousse, the ancient Roman town of Hadrumetum, and the subject represents the Cortege of Neptune. In the center is shown Neptune upon his car, while there are a great number of medallions in which are placed various sea-deities and other subjects. This mosaic is very well executed and shows a variety of brilliant colors and the figures have a lifelike appearance. Upon the walls are a great number of mosaics which come from tombs. The subjects present scenes from real life, including animals, birds, and fish.

VITAL RHYTHM.

By Dr. A. Drzewina.

The importance of habit in biological phenomena is so evident that life may almost be said to consist of habit. In the physiology of man, animals, even plants, habit establishes a definite rhythm which dominates the life of the creature. If chestnut trees of the variety known in France as "March 20th" bloom a month in advance of the rest of the species, it is because former conditions of life have impressed upon this variety a particular seasonal rhythm, which has since been maintained by a sort of habit, independently of the conditions which caused it. The example of spring wheat is equally instructive. Wheat which had been cultivated in the south of Germany and had acquired the seasonal habits appropriate to that region was sown in Scandinavia. It adapted itself so rapidly to the northern climate that in a few years a variety of wheat was developed which had acquired a habit of maturing much more rapidly than its German ancestor and retained this habit when it was sown in southern Germany. Thus was produced a variety of wheat which, though sown in spring, ripens as early as winter wheat sown in the preceding autumn.

The life of littoral, or seashore, animals, is intimately connected with, and to some degree regulated by, the ebb and flow of the tide. As the tidal movements are rhythmical, the animals show a rhythm of the same period, which persists for some time after their withdrawal from the influence of the tide. This has been proved by recent experiments of Bohn on sea anemones, annelid worms, and mollusks.

Convoluta roscoffensis is a little ciliated worm found on the beaches of Brittany, where it forms vast bright green patches of incessantly varying shape and size. These colonies are submerged for about two hours before and two hours after high tide. At this period the worms bury themselves in the sand to escape the buffeting of the waves. When the tide ebbs, they reappear on the surface of the sand. These alternate movements, evidently acquired, have in the course of generations become independent and spontaneous, so that they are continued in the aquarium where there are neither waves nor tides. The worms, imprisoned in a glass tube with wet sand, move to the top of the tube at low tide and to the bottom at high tide. They even follow the irregularities of the tide, moving slowly at neap tide and quickly at spring tide. These alternating movements continue for several days after the worms have been taken from the beach.

Littorina rudis, a very common gasteropod, is found retracted into its shell at neap tides in summer when the rocks on which it dwells are strongly heated by the sun and not submerged for days. On the coming of the spring tide, which covers the rocks twice daily, the mollusks emerge from their semi-torpid state and crawl about on the wet rocks, seeking the darkest places. This vital periodicity, due to the movements of the tide, persists after the mollusks have been removed from their natural habitat. If they are placed, while in the torpid state, in an evaporating dish, they suddenly awake and move with unerring precision toward the shaded part of the vessel when the tide reaches their native rocks, although they have had no bath to relieve their desiccation and wash away the waste products to which their auto-intoxication and stupor are due. In addition to this fortnightly rhythm they exhibit a rhythm of smaller amplitude and of the ordinary tidal period.

A vital periodicity of the same character, and equally persistent, is observed in the sea anemone (*Actinia*), though not invariably. In general, the vital rhythm in littoral animals is more or less strongly marked in proportion to the sharpness of the contrast between the conditions of existence at high and low tide. Anemones living in the pools of water that are left by the receding tide are subjected to little, if any, desiccation and consequently they cannot exhibit any striking tidal periodicity. But anemones living on rocks which are exposed at low tide and submerged at high tide show a clearly marked periodicity. In this case, also, the vital rhythm is manifested in the aquarium, where the anemones, though always submerged, close spontaneously at the hour of low water and gradually open as the tide rises.

A similar vital rhythm has been observed in the vegetable kingdom. According to the recent observations of Fauvel and Bohn, *Pleurosigma aestuari*, a marine alga of the diatom family, behaves much like the *convoluta* worm under the influence of the tides. At high water these microscopic organisms lie buried in the sand, but at low tide they emerge and form a thick brown layer on the surface. When the diatoms are transferred to the aquarium there is a con-

flict between the tidal rhythm and phototropism, or tendency to seek the light. At night they remain buried through all changes of the tide. Hence they emerge either once or twice in each twenty-four hours according to the number of low tides in daylight.

Some biologists have endeavored to explain these curious phenomena by assuming the existence of a "memory of the tide," and Forel has attributed a "memory of time" to bees which, according to his observations, invade the dining room at the hours of those meals at which sweets are served, but at no other time. But, though bees and even annelid worms may possess some sort of memory, it would be absurd to ascribe memory to diatoms, which show not the slightest trace of a nervous system. Bohn simply records the facts, without attempting any explanation, either mechanical or psychological. Le Dantec groups the phenomena under the title "habit," which explains nothing but is convenient for the classification of facts.—Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from La Science aux XXme Siècle.

THE MEASURELESS REMOTENESS OF THE STARS.*

THE SCALE OF THE STELLAR UNIVERSE.

BY J. F. LANNEAU.

IN February, 1901, there suddenly appeared in the northern sky a previously unseen star about as bright as the familiar Pole star. It quickly brightened, and in less than three days vied with Sirius, the brightest of the stars. Then, fading rapidly for a month, it resumed its former invisibility. The sudden blazing up of that star to a 25,000-fold brightness, really occurred over three centuries ago—occurred before Jamestown's settlement, whose tercentennial is now being celebrated. Such that star's distance, that its light flashing from its unthinkable remoteness had just reached us in February, 1901!

Most of us think we can see a countless multitude of stars. But contrary to this popular impression, the visible stars are really quite limited in number. They have been carefully counted and found to be, all told, less than 7,000. Of course the telescope brings into view millions more—a countless host. But even from a favorable standpoint on the earth's equator, scanning the evening sky from pole to pole throughout the year as its twinkling lights pass in review, we cannot count as many as 7,000 stars. Of the half of them in the sky any night some 1,500 are concealed by the murky air all around the horizon. At no time can an observer see more than 2,000 stars.

How far off are the stars? Too far to state in miles. To name the distance to the nearest star in miles, would be like stating the distance to the moon in inches. For stellar remoteness we need a large unit—not less than the distance from the earth to the sun. Some hundreds of thousands of this long unit express somewhat intelligibly the star's distance from us—provided the unit distance is comprehended.

Unfortunately, any mental picture of this earth-sun unit distance must be inadequate. We may aid imagination, however, by noting the time of transit of some missile or swift vehicle.

A balloon soaring sunward may aid conception. Assume that Columbus in the year 1492, to signalize his discovery of America, had sent up a balloon to the overhead sun; and suppose that, regardless of failing atmosphere, it rose swiftly, steadily 37 1-3 miles every hour until it reached the sun. When did it reach its destination?

Columbus retraced his uncertain course across the broad Atlantic, presenting the new-found western continent to Ferdinand and Isabella. He made other long voyages—other discoveries. Still the balloon was swiftly mounting sunward! More than a century passed. Jamestown was settled. Virginia's forest witnessed the romance of Pocahontas. The "Mayflower" landed at Plymouth Rock; and later, New England nestled in the wilderness. Lexington's guns heralded a new flag—the stars and stripes. Independence was declared. Then, late in the new nation's natal year, the balloon which had mounted steadily sunward 37 1-3 miles every hour for wellnigh three centuries had just reached the sun. Its long flight measured our needed unit of distance; 275,000 times this unit is the distance to the nearest star—the bright southern star α Centauri. What then the distance to the stars beyond? What the distance to those so remote in the depths of space that powerful telescopes bring them only faintly into view?

For these stupendous distances our earth-sun unit—the 93 million mile unit—is too short. For these staggering stellar reaches through boundless space, a special new unit of length must be devised. It is called the light-year—meaning the distance light flashes in a year.

We must realize if possible, something of the significance of this unit—the distance light goes in a year.

The first creation from primal chaos was light. "Let light be, and light was." It moves with the swiftest speed known. Its unrivaled velocity—first learned in 1675 by noting eclipses of Jupiter's moons, more recently proved experimentally — is 186,330 miles per second; this distance is over seven times the distance around the world. If a light ray, instead of moving as it does in a straight line could trace a circle, it would flash seven times around the world in a second. Yet, at its unrivaled rate, light in one year traverses less than a fourth of the distance to the nearest star, for α Centauri's distance from us is over four light-years.

Sirius, the brightest of the stars, is eight light-years from us; Arcturus, 24 light-years; and Polaris, the familiar north star, is 60 light-years distant.

Some of the stars just visible to the unaided eye are more than 300 light-years distant from us. Many of those which are faintly seen through a large telescope are 3,000 light-years off; and others are at distances of many thousand light-years. With this insight into the vastness of stellar reaches we may in some degree understand that any two visible stars, though seemingly side by side in the sky, are in reality distant from each other several light-years, and that the stars are not crowded. Their seeming nearness to each other is but the effect of distance. Closely grouped apparently, as in Perseus or Scorpio, or in any of the constellations, no two stars are really neighbors. Any two of them, on the average, are twice as far apart as are the earth and the nearest star. Often the two apparent companions are nearly in the line of sight—one far beyond the other. For instance, in the northern constellation Cassiopeia are two faint stars, Eta and Mu, seemingly side by side; one is distant from us 21 light-years; the other, 9 light-years. The two, then, seemingly close neighbors, are in reality separated a distance of at least 12 light-years—about three times our distance from the star α Centauri.

The familiar Big Dipper is outlined by seven stars: three in a curve trace its handle, and four its bowl—the two farthest from the handle pointing to the North Star. Could we stand on any one of the seven stars in that group, the nearest of the others would appear to us about as the star Sirius appears from the earth.

We speak of the "fixed" stars in contradistinction to the planets. But the stars are not even relatively fixed; they are in motion, and in all directions; each in its independent course in swift, steady motion. They are certainly changing their relative positions, and the changes are not perceived simply because of what has been noted—their inconceivable distances from us and from each other. Incontestable proof of their real, though to us imperceptible change, is found in comparing star charts made long centuries ago with charts recently made. For instance, the bright star Sirius mapped by Ptolemy seventeen centuries ago, is shown by modern charts to have moved southward about the apparent breadth of the full moon.

A moon-breadth in seventeen centuries! Yes, but a moon-breadth at our moon's distance is two thousand miles; at our sun's distance, nearly a million miles; and at Sirius' distance, a moon-breadth is hundreds of thousands of millions of miles!

Viewed through a telescope a star seems to be a mere point of light. The larger the telescope, the more of the star's light entering its great eye, the brighter the star's image, but the image is still a point. The star's really vast volume, millions-fold larger than this earth, seemingly shrinks to a mere bright speck because of its inexpressible remoteness from us. How can it so shine from the profound depths of space? Does it receive light from the sun and reflect that light to us as do the planets? Is the star's light only reflected sunlight? No; each star, as the spectroscope proves, shines by its own energy—is itself a sun. Our sun and those remote twinkling stars reveal the same essential structure. Each star is indeed an immense glowing body, dispensing freely its own heat and light. Some of them—notably Canopus and Arcturus—are vaster in volume than the sun. Could the sun withdraw from us and retreat into the depths of space, on its way to one of those remote stars it would itself become a star and grow fainter and fainter until invisible. Our sun, like these other stars, is speeding through space; it is advancing toward Hercules—or more nearly, toward the bright star Vega, now conspicuous in the northeast. The spectroscope confirms this fact. Moreover, it shows that the sun's steady motion toward Vega is at the rate of some twelve miles a second. In a year, we move in that direction four times the earth-sun distance, and in some four thousand centuries we will reach Vega's present region of space—but not Vega. Its motion meanwhile will have borne it to new remoteness. We shall then have a new pole-star, but shall still see in the north the same Big Dipper—a little bent doubtless—and the same Galaxy, the same Zodiac, the same glittering constellations as we do now.

That since the "Beginning" we, with the sun, have been steadily speeding on and on through interstellar space without once meeting or passing a single lonely star, brings home to our realization as no other consideration can, the amazing amplitude of cosmic space, the completeness of the isolation of each star from all others, the supreme magnificence of the scale of the stellar universe.

* Abstracted from Popular Astronomy.

UTILIZATION OF BOOKBINDERS' WASTE.

BOOKBINDERS' waste can be profitably used for the production of papier maché for bas reliefs, vases, urns, frames, clock cases, etc. All kinds of paper cuttings, or pasteboard residues, can be employed. The other ingredients are finely sifted ashes, particularly of hardwood, and flour paste. The papier maché is made as follows:

The refuse is reduced to small fragments, placed in a vessel filled with water and left to dissolve. When thoroughly soaked the water is lightly pressed out of the mass which is placed in a mortar and well pounded. After this, the mass is placed in a strong linen cloth and as much of the water wrung out as possible. The balls thus produced are dried, either in the sun, or at the fire. The dried balls are rubbed on a rasp so that the flocks produced are like cotton to the touch. These flocks are then mixed with flour paste on a board with a wooden spatula into a dough. This dough, which forms one-third of the mass to be prepared, is arranged in a ring, with twice its bulk of finely sifted ashes in the center. Water is added, a little at a time, mixing gradually, until all the ashes are wetted. Finally, the ring is incorporated with the wetted ashes.

This mixture is placed in the mortar and well pounded, yielding the papier maché ready for use. If it is desired to keep it moist for a long time, it can be placed in glazed earthenware, and stored in a cool place.

Such papier maché may be used instead of modeling wax. Take, for this purpose, a piece of the mass; press it out flat in the size needed for the bas relief, coat one side with flour paste and press it on any desired support. Take out any superfluous moisture by pressing a folded linen cloth over it. After this, we can lightly engrave the outline of the low or high relief, with an embossing tool, raising the flattened high spots by fresh applications of maché. This possesses various advantages as compared with modeling wax.

The embossing tool works more easily in the soft dough than in wax. If part or all of the mass should begin to dry it may be gone over with a fine brush dipped in water, and the mass will work as easily as ever.

When the finished bas relief is perfectly dry, it is coated with dilute flour paste with a hair brush, and when this is dry the entire surface is burnished with a bone polishing tool. It is now ready to make impressions from with molding wax. It may also now be coated with thin glue water, again dried and smoothed off in the manner described. This last preparation of the surface fits it for any application of oil or heavy-bodied water colors, or for gilding. After the work has been painted or gilded, it is customary to give it several coats of spirit varnish, and after this is dry, neither heat nor cold, moisture, dust nor fly specks can injure it. The dust can be removed with a soft dusting brush and the fly specks with a moistened rag.—"Verwerthung von Abfallstoffen aller Art."

The price of diamonds is tending upward, for some months the importation of the stones having shown a decline, owing to the lessened output from South Africa. This is probably more a market manipulation than a real scarcity.

APPLICATION OF FERRO-CONCRETE FOR BRIDGE FOUNDATION CAISSONS.

A NEW METHOD OF CONSTRUCTION.

BY THE ENGLISH CORRESPONDENT OF THE SCIENTIFIC AMERICAN.

In the construction of a steel bridge for the new Strabane and Letterkenny Railroad over the River Foyle (Ireland) an interesting departure from the general procedure in connection with the building of the piers was made. The latter were sunk to the foundation level by means of caissons; but instead of using either a metal caisson throughout to carry the superstructure, or continuing the brickwork upon a metal curb, they have been constructed entirely of ferro-concrete. The principle adopted was evolved by Mr. T. Malcolm McAlpine, of the contracting firm of that name of Westminster, London, who carried out the undertaking, and possesses many interesting features. The caisson is not constructed in one huge monolithic structure, but is built up of a series of sections superimposed to the requisite height, the bottom section alone being provided with a cutting edge. The system upon which the sections were carried out may be best realized from the accompanying illustrations. They were prepared in molds on the river bank, and were left for a period of some four weeks, so as to become thoroughly hardened. The lowermost section carried a number of vertical rods of ¾ inch diameter, to bind it to those superimposed. These reinforcing rods were of sufficient length so that the upper extremities, when the section was sunk into the requisite position, projected above the level of high water. After the lowest section had been placed *in situ*, the building up of the additional sections was a simple operation. Each successive section was provided with holes corresponding in position and dimensions with the vertical iron rods, and was then lifted bodily by a crane, the section being guided into place over the rods, so that it ultimately came to rest firmly and securely upon that immediately beneath it, while at the same time the vertical alignment was well preserved. Each section was tightly and thoroughly bonded to that adjoining, by the provision of a narrow groove upon the upper edge of the section and a corresponding wedge upon the under side of that above it, so that when lowered the wedge fitted into the groove. The joint between the two sections was secured by a sausage joint of cement mortar inclosed in linen. This was laid in the groove, and the pressure of the descending section with its wedge-like edge dug into the soft cement mortar, thereby making a joint which was found to be absolutely water-tight. The concrete used for the molding of the sections consisted of four parts of gravel to one of cement, and each section weighed from 7 to 8 tons. By the adoption of this system, the work of constructing the foundations to the piers was considerably expedited and facilitated. No staging, piling, or hydraulics were required at any part of the work, the lifting and setting being accomplished throughout by means of a 10-ton crane. The cost of executing these foundations proved to be one-half of that which would have been entailed had the caissons been constructed of metal.

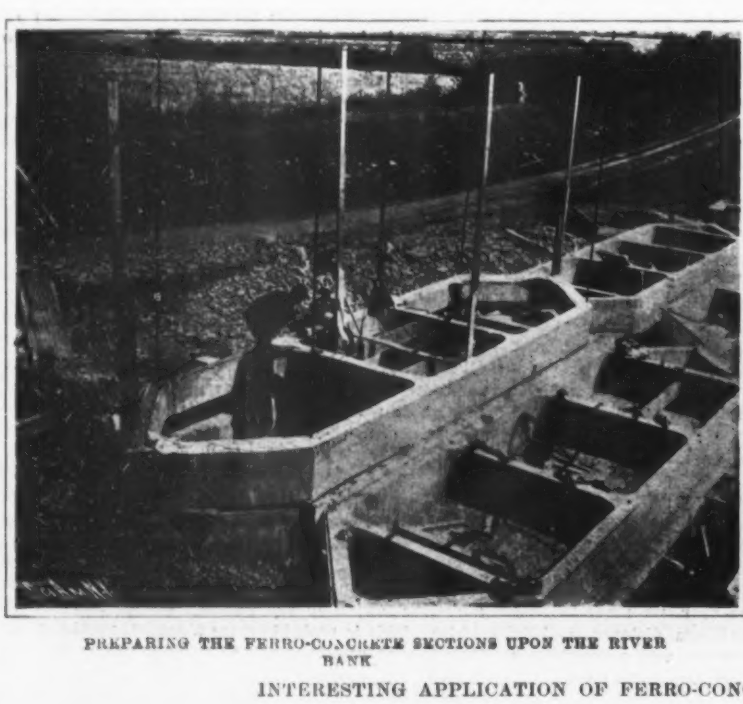
SETTING THE CAISSON SECTIONS IN PLACE.

GUIDING A SECTION OVER THE REINFORCING RODS UPON SECTION BELOW.

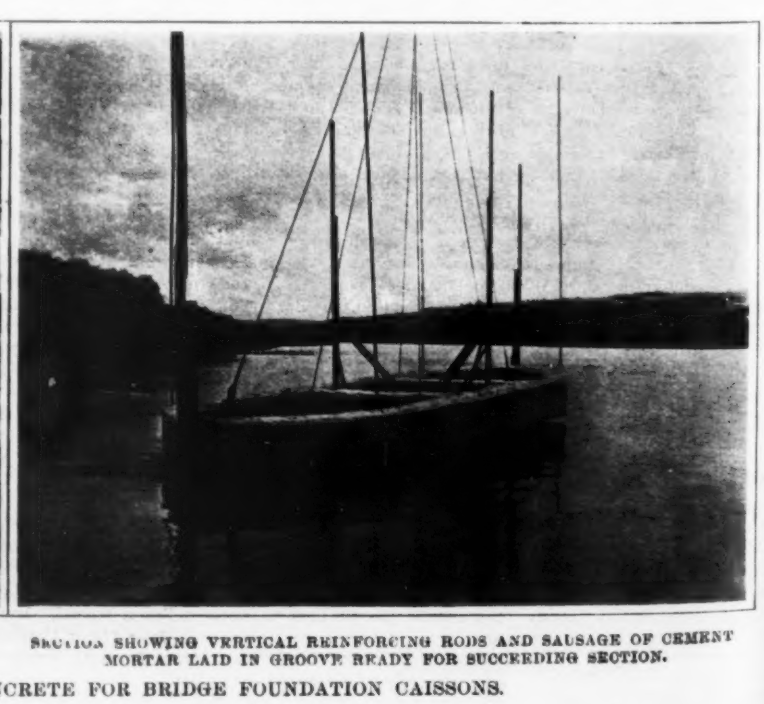
TEN-TON CRANE USED IN SETTING THE CAISSON SECTIONS.

According to the Railway and Engineering Review the German government authorities have decided to build an electric railway from the Essen coal and iron district, across the semi-mountainous Eifel region, to the Saar and Lorraine districts. The object is to secure the cheapest transportation for heavy goods from Lorraine, which produces enormous quantities of low-grade iron ore, thus avoiding the costly shipment to the furnaces of the lower Rhine.

Simple Method of Testing Precious Stones.—Mr. Meyer D. Rothschild in the Jewelers' Circular Weekly suggests a simple test, applicable to a number of stones, that can be made by any jeweler who will exercise care in its execution. Hydrofluoric acid or "white acid" (a mixture of ammonia and hydrofluoric acid) is used. The acid should never be allowed to come in contact with the skin, as it is very poisonous and highly corrosive, producing painful sores and ulcers. The stone to be tested is handled with forceps and immersed one minute in the acid; then it is removed and the acid is washed off. The test is applicable only to diamond, ruby, sapphire, spinel, emerald, aquamarine, precious topaz, tourmaline, garnet, and kunzite, which are unaffected by the hydrofluoric acid. The test is not applicable to turquoise and opal, which are rapidly etched or eaten away by this acid, nor to peridot and the quartz gems, as amethyst, false topaz, crystal, agate, etc., which have their surfaces dimmed and require repolishing. The genuine reconstructed and artificial ruby is also unaffected, while all imitations made of paste, as imitation ruby, sapphire, emerald, etc., are rapidly attacked.



PREPARING THE FERRO-CONCRETE SECTIONS UPON THE RIVER BANK.



SECTION SHOWING VERTICAL REINFORCING RODS AND SAUSAGE OF CEMENT MORTAR LAID IN GROOVE READY FOR SUCCEEDING SECTION.

INTERESTING APPLICATION OF FERRO-CONCRETE FOR BRIDGE FOUNDATION CAISSONS.

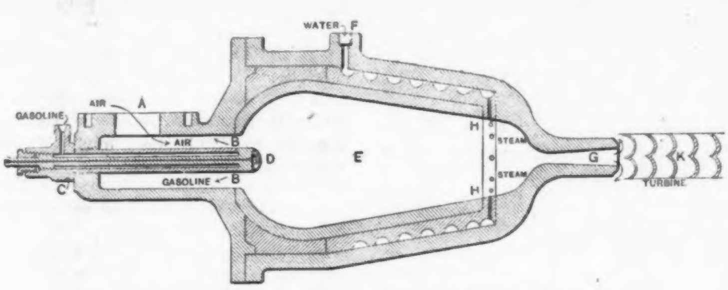
NEW GAS TURBINE AND CENTRIFUGAL AIR COMPRESSOR.

A STEP IN A NEW DIRECTION.

BY THE PARIS CORRESPONDENT OF THE SCIENTIFIC AMERICAN.

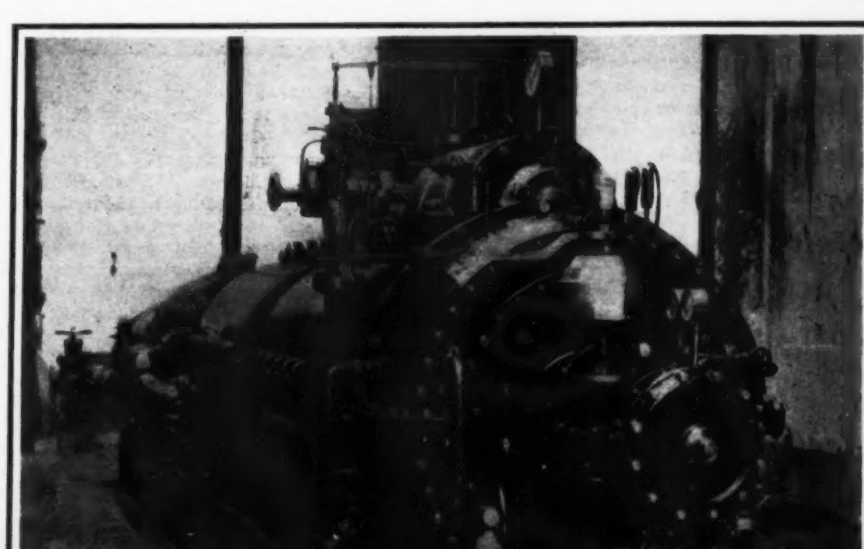
AIR COMPRESSOR OF CENTRIFUGAL TYPE COUPLED TO TURBINE.

Following the success which has been obtained with the steam turbine within the last few years, inventors were led to seek for an internal combustion turbine which would apply some of the well-known advantages of the gas motor to the turbine principle. Owing to the difficulties which were found when it came to experimenting with the gas turbine, the question is far from being solved at the present time, and, in fact, may be said to be in its initial stage. But there are a number of inventors working upon the problem in Europe, and it is to be hoped that some practical outcome will result from their experiments. The writer had occasion to examine a gas turbine which is now being tried at Paris. This machine is completely finished and set up on a foundation. It is coupled direct on the shaft of a rotary air-compressor. M. Alfred Barbezat, a well-known engineer, who is superintending the experiments, gave the following information about the new machine. Not only the turbine, but also the present form of rotary air compressor, is built upon a new principle, the air compressor having been designed specially for working at high speed and can thus be coupled directly to a steam or gas turbine, which is an advantage for different kinds of work. Regarding the internal combustion turbine in the first place, it is the invention of Messrs. Armengaud and Lemale, two French engineers who have had considerable experience in this field. The first machine of the kind which they designed was built at the works of the Turbo-motor Company, at Saint-Denis. After some trial it was decided to redesign it, and accordingly a second turbine was built, with the co-operation of M. Barbezat, which is the one illustrated here. The present invention is designed to combine the great advantages of the gas engine, namely the suppression of the boiler and the increase in economic yield, with the qualities which belong to the steam turbine, reduced size, lightness, uniform movement, with a resulting simplicity and ease of starting up and regulating the machine. The accompanying diagram will give an idea of the internal combustion system employed. It is to be remarked, however, that in this case there is a continuous combustion and vaporization of water and not a succession of explosions as in the gas engine. In principle the apparatus comprises a main combustion chamber which is supplied by three openings with air, gasoline, and steam. A continuous air current is sent into the chamber at *A*. The air for this purpose is compressed by a high pressure air compressor mounted upon the turbine shaft and running consequently at a high speed. Through a series of spray openings *B* is sent a continuous spray of oil under pressure which mixes intimately with the air. It is ignited by means of the incandescent wire *D*, energized by an electric current. The combustion which is thus brought about will furnish a high heat in the inclosed chamber at *E*, this being about 1,800 deg. C. The chamber is also supplied with a steam jet whose delivery can be regulated, and it is formed by sending water in by the orifice *E* and causing it to circulate around the heated chamber by a spiral groove, as will be noticed. This gives steam at the series of openings *H* and it then enters the combustion chamber under pressure. By regulating the supply of steam, we obtain a mixture which works at any desired temperature below 1,800 deg. C. After expansion in the outlet pipe *G* it works upon the turbine wheel *K* which is of the steam turbine pattern in general and has the vanes cooled in a suitable manner.



SECTION THROUGH STEAM GENERATOR.

A number of calculations relating to the combustion and the theoretical working of such an apparatus have been made and curves are established to show the results, but as these are in general the outcome of formulæ which require considerable space, we will mention only some of the leading points which were established for the turbine. By causing the combustion of ordinary gasoline in air, the carbon *C* and the hydrogen *H* which it contains are transformed into carbonic acid CO_2, and water vapor H_2O. These reactions are accompanied by a certain production of heat which can be calculated and which allows us to find the average calorific value for the oil employed here, seeing that the oil contains per kilogramme (2.2 pounds), 851 grammes (30 ounces) of carbon, 142 (5 ounces) of hydrogen, and 7 (0.2 ounce) of oxygen. It is known that one kilogramme of carbon burning completely to the state of CO_2 gives an amount of heat represented by 8,100 calories, and the same weight of hydrogen burning to form water will furnish 29,000 calories. As on the other hand 2 grammes (0.07 ounce) of hydrogen combine with 16 (0.56 ounce) of oxygen to give 18 grammes (0.63 ounce) of water, and 12 grammes (0.42 ounce) of carbon combine with 32 (1.1 ounce) of oxygen to form 44 grammes (1.55 ounce) of carbonic acid, one kilogramme of oil containing 141.1 grammes (4.97 ounces) hydrogen will furnish heat equivalent to 11,000 calories. The amount of oxygen needed for the complete combustion of the oil is calculated to be 3.4 kilogrammes (7.5 pounds), and hence knowing the composition of air we find that 15 kilogrammes (33 pounds) of air are needed for the combustion of one kilo of petroleum, or we may allow 18 kilogrammes (39.7 pounds). The result of the combustion of one unit of oil with 18 of air gives 61 per cent nitrogen, 16.5 carbonic acid, 6.7 water with an excess of 15.8 per cent air. Hence we are able to calculate the temperature of combustion, knowing the specific heat of the gases which are used. Omitting the calculations, the temperature, allowing for heat losses, is found to be 1777 deg. C. By introducing a certain amount of steam we can lower this heat to any desired point. What is especially of interest to know is the efficiency of the turbine, this being the relation between the



NEW INTERNAL COMBUSTION TURBINE.

power obtained on the shaft and the energy represented by the combustion. First deducting for the power needed to run the air compressor, the efficiency of the system is found by the proper curves to be about 18 per cent at the usual working point, with a temperature of 920 deg. C. at the exhaust and an initial pressure of 15 atmospheres. The consumption of petroleum is found to be 400 grammes (14.1 ounces) per effective horse-power. It is found also that it is best to use high pressures and high temperatures in the apparatus. One of the engravings gives a general view of the turbine which has already been constructed.

Aside from the question of the gas turbine, the new air compressor which we illustrate here has some interesting features. The inventors wished to design a rotary compressor working on the centrifugal principle. Prof. Rateau, well known for his work upon steam turbines, supplied the theoretical data for the machine, and it was built at the works of the Brown-Boveri firm of Baden, Switzerland. The present compressor is designed to furnish the air which is needed for the gas turbine just mentioned, but it can also be used in other cases, as it can be coupled direct to a steam turbine and works at a high speed. Up to the present the great speed of the steam turbine allowed it to be used only for dynamos and helices with direct coupling. The use of a centrifugal air compressor thus extends its applications and a group of this kind can be used to deliver a great volume of air at a moderate pressure, such as is needed for blast furnaces, Bessemer converters, in mines and elsewhere.

The compressor is made up of a series of disk-wheels resembling steam turbine disks. Each wheel unit has two main parts, the wheel proper and the diffuser. The action of the wheel causes a certain compression of the air due to centrifugal force, while the diffuser, consisting of orifices having an increasing section, acts to reduce the speed of air flow at the outlet and to transform the kinetic energy into potential energy or pressure. The static pressure added to the pressure which is due to the absolute speed of the air is found to be 1.6 times what would be given by the wheel alone, from measurements which were made. Referring to the illustration, the compressor, coupled here to a steam turbine, is made up of three main cylindrical parts, containing in all about twenty of the above-mentioned elements. Each of the parts is smaller in diameter than the preceding, seeing that the dimensions of the wheels must diminish as the compression becomes higher. All the wheels of the same cylinder are, however, of the same diameter, for practical reasons.

As the weight of the revolving parts is small, there is no trouble with the bearings either from pressure or oiling. When working at a high speed of 4,500 R.P.M. there is scarcely any vibration. Each cylinder is cooled by a water jacket, and the air is raised to a temperature of only 50 deg. C. above the ordinary. Besides, the water jacket acts to deaden the noise of the machine. The present compressor is designed to work at 4,000 R.P.M. and furnish one cubic meter (35.3 cubic feet) of air per second at a pressure of five atmospheres. In this case it takes about 400 horse-power. Its yield appears to be better than that of the usual piston compressor, and besides it has several advantages, there being a wide field of application, a very low cost of running and surveillance, and all the advantages which are in favor of the steam turbine over the steam engine.

THE DEVELOPMENT OF ARMORED WAR VESSELS.—VII.

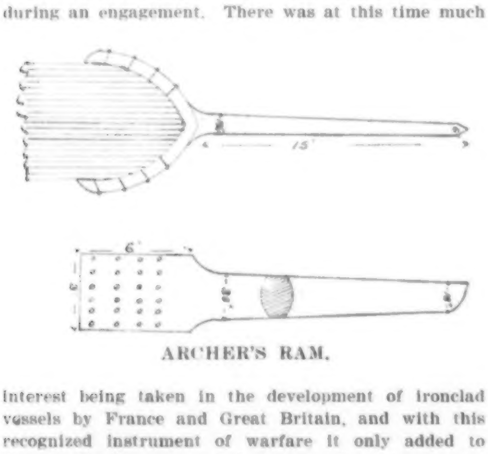
ARMOR PLATING IN THE UNITED STATES.

BY J. H. MORRISON.

Continued from Supplement No. 1657, page 220.

Prof. Henry Morton, of Stevens Institute, wrote a paper on the Stevens battery that was published in the Engineering of London on March 26, 1897, where he says it was the "Thomas Powell" ran into a cribwork dock, from which Mr. Stevens argued: "If a light-built river steamer could so cut into and damage a solid cribwork, what would an equally rapid steamer with iron hull accomplish if hurled against the side of an ordinary wooden or iron vessel?" As the "Thomas Powell" incident happened in 1868, Prof. Morton is in error; for Robert L. Stevens had been dead twelve years, and Edwin A. Stevens died during the same year. He was correct so far as showing that the battery did not have a ram bow at the time of the "Powell" incident, though it is claimed there was a ram fitted to the vessel at a later date.

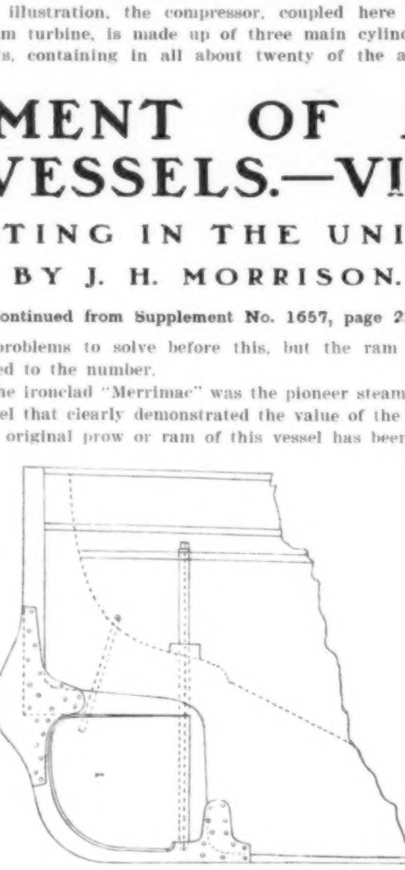
From the commencement of the domestic construction and the rebuilding of the armored naval vessels of the Confederate States government during the rebellion, they were all fitted with a ram or beak; it is not known that there were any exceptions. The first steam vessel in any navy having a ram was the "Manassas" of the Confederate States navy in 1861. This ram was of cast iron, and it must have been a comparatively small fixture for the purpose intended, as we find by a report of a survey made on the U. S. S. "Richmond" after being rammed by the "Manassas" the following: "And find that three of her outside planks under the port fore channels are broken below the water-line, between two timbers, causing a considerable leak, which has been temporarily stopped, so that she is reported to make 8 inches of water in 24 hours." An officer on the "Richmond" at the time subsequently said: "The ram had made a hole in our side through which the water was pouring in a stream as large as a man's leg." This would show that the hole made by the ram was about 5 inches or 6 inches diameter. The most reliable accounts say the ram was 5 inches deep at the forward end by 3 feet to 5 feet long. This vessel, after the short and inconsequential engagement, so far as damage was concerned, at the passes of the Mississippi River, certainly stirred the naval powers of the world as to the value of the ram on an ironclad vessel when it was skillfully handled during an engagement. There was at this time much



ARCHER'S RAM.

interest being taken in the development of ironclad vessels by France and Great Britain, and with this recognized instrument of warfare it only added to the complication of untried systems of construction of armored vessels, that made it more exacting for the naval designers than ever before. They had plenty of problems to solve before this, but the ram only added to the number.

The ironclad "Merrimac" was the pioneer steam war vessel that clearly demonstrated the value of the ram. The original prow or ram of this vessel has been but



"TACONY."

imperfectly described in the many accounts given of the vessel. As this ram or beak has some historical interest, for the reason that it was the first weapon of its type on a *steam ironclad naval vessel* that was put to service in actual warfare, a few excerpts from authorities who were in the Confederate navy at the time of the rebuilding and service of the vessel, will show the comparative limited knowledge on the subject of ironclads and of rams at that period, but no more so with the Confederate naval authorities than with any of the naval powers of the world; as well as some details of this ram not heretofore made public.

Commander John M. Brooke, who was of the Ordnance Bureau of the Confederate Navy Department, was a witness before a joint special committee of the Confederate Congress on an investigation of the Confederate Navy Department in 1862-63, where he said:

Question. "Was it a part of the original plan that she (the "Merrimac") should have a ram?"

"It was embodied in the original plan; we always intended that she should be a ram. All ironclad vessels are built as rams. Putting a beak on a vessel depends altogether upon the opinion of persons. The stem of a strong vessel serves as a cutter or beak without being at all prolonged in advance of the ship proper. . . . A long beak was to have been cast for the 'Patrick Henry,' or 'Jamestown,' but it was laid aside because the foundry was required to have guns cast." [These vessels were the captured side-wheel steamships that formerly ran between New York and Richmond, Va.]

Speaking of the opinion of Confederate naval officers of ironclad rams, he said: "But I know that so little was known by our people generally, officers included, about ironclads, that very few were willing to express an opinion until the experiment had been made."

Question. "The 'Merrimac' had a beak upon her, had she not?"

"Yes, she had a piece of cast iron, but it was left, they say, in the 'Cumberland.' It was not determined to put it on in that particular form. It was supposed that the projection beyond the shield that was submerged would be sufficient as a beak; but Mr. Porter decided to put on the iron beak which she carried. The vessel was pretty well advanced when the beak was put on. The shield was up."

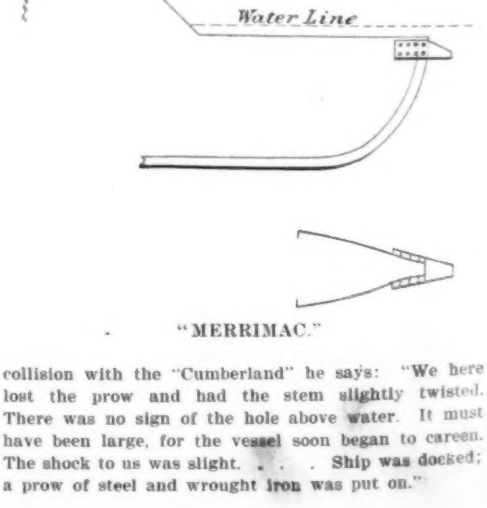
The Hon. Charles M. Conrad, who was the chairman of the Committee of Naval Affairs in the Confederate Congress, in his testimony before the same investigating committee, said:

"I do not know at what time the 'Merrimac' was commenced, nor at what time it was determined to make her a ram. I did not hear of her being a ram until long after I had heard that she was being covered with iron, and was somewhat surprised when I did hear it, owing to the opinion I heard Mr. Mallory express with reference to rams. This was somewhat after Mr. Stevenson recommended iron-plated rams." [The latter was one of the projectors and owners of the "Manassas."]

On July 18, 1861, the Secretary of the Confederate Navy made a report to the Confederate Congress that the "Merrimac" had been docked, and asked for an appropriation of $172,523, as it had been determined to shield her with 3-inch iron, and to arm her with the heaviest ordnance, but there is no mention of a prow or ram for the vessel. The work of rebuilding the vessel had at this time been commenced. The department appears to have been a law unto itself; for they made their plans and commenced work on the vessels, and then asked Congress to make an appropriation for the specific object.

John L. Porter, naval constructor, in a paper on "The Battles and Leaders of the Civil War," says: "Her prow was of cast iron securely fastened to the ship, and so secured that though it was broken in two by striking the 'Cumberland' a glancing blow, the fastenings to the vessel were not broken loose."

Lieut. Catesby Ap R. Jones, executive officer of the "Merrimac": "The prow was of cast iron wedge shape and weighed 1,500 pounds. It was about two feet under water and projected two feet from the stem. It was not well fastened." Speaking of the



"MERRIMAC."

collision with the "Cumberland" he says: "We here lost the prow and had the stem slightly twisted. There was no sign of the hole above water. It must have been large, for the vessel soon began to careen. The shock to us was slight. . . . Ship was docked; a prow of steel and wrought iron was put on."

D. B. Phillips, surgeon of the vessel: "The prow not being well put on was twisted off and lost in our first encounter with the 'Cumberland.' . . . I am also satisfied had not our prow been lost we should have sunk the 'Monitor,' when we rammed her on March 9, 1862."

Lieut. John T. Wood, of the "Merrimac": "The prow was of cast iron projecting four feet, and badly secured, as events proved. . . . The ram was left in the side of the 'Cumberland.'"

Midshipman H. B. Littlepage, of the vessel: "The only damage sustained by her worth mentioning was by ramming the 'Monitor' with her wooden stem, her cast-iron prow having been wrenched off the day before in the 'Cumberland.' She was then thoroughly overhauled and equipped for fighting an ironclad. A prow of steel and wrought iron was put on."

H. Ashton Ramsay, acting chief engineer of the vessel, to the writer: "At the time this vessel rammed the 'Cumberland' in Hampton Roads in March, 1862, the ram consisted of cast iron, the casting weighing about a ton, which was built into the wooden prow of the vessel. It was triangular in shape, about six inches wide at the extreme end, and extending back about three or four feet, embracing the wooden stem, to which it was secured by bolts passing through the flared sides of the casting. This ram, and the method of securing it, proved very temporary, as it was broken off at the time of the collision with the 'Cumberland.' Later, after the fight with the 'Monitor,' a much more effectual prow was forged of wrought iron, and extended well back into the vessel some six or eight feet, to which it was thoroughly bolted; but there was never an opportunity to use the new ram. . . . Some of the reports concerning the engagements of the 'Merrimac' with the 'Cumberland' and 'Monitor' mention that the ship was leaking badly after her encounter with the 'Monitor' on account of the cast-iron prow before described having been broken off, but as a matter of fact no considerable amount of water came into the vessel. There were water-tight collision bulkheads both in the forward and after ends of the vessel, and so little water came in that it was only necessary to use one of the bilge pumps, and this working slowly."

Several of these papers were written for the Southern Historical Society of Richmond, Va.

The best description of the origin and dimensions of the original prow or beak of the "Merrimac" is given by J. W. H. Porter, a son of J. W. Porter, who was the naval constructor of the Confederate States navy, to the writer: "I have in my possession, left by my father, the original plans of the 'Merrimac' which were approved by Secretary Mallory. Mr. Porter did not contemplate that she would be used as a ram, as the timbers in the old ship had not been arranged for that purpose; but a few days before (?) she made her fight Capt. Buchanan told him he would like to use her for that purpose, consequently Mr. Porter had an iron beak cast in the navy yard, as a sort of entering wedge, and bolted it on her stem. It was rude and hastily gotten up, as everything was being rushed to get the ship out before McClellan advanced from Yorktown. It was not on her original plan, but Mr. Porter subsequently added a rough sketch of it in lead pencil. It was something like the drawing I inclose. It projected two feet in front of the stem, was about 12 or 15 inches deep on the face, and weighed about 1,500 pounds. The 'Cumberland' was struck a glancing blow, and the impact broke the beak in two at the stem. The bolts held. The second beak was similar, but was more carefully made. It was somewhat shorter, projected about 15 inches, and ran back about 13 feet. It was made of steel and wrought iron, and the bow timbers were strengthened. . . . I saw the beak on the 'Merrimac' a number of times, and the description I gave you of it as to size, weight, and shape was taken from Mr. Porter's notes made at the time. Commenting on the subject a short time afterward, he wrote: 'As far as the ram is concerned, it was an idea of my own entirely. Very little was known about them at the time, and for the want of something better to make one out of we made it of cast iron. But scarcely anyone thought it would ever be used. It was fitted to the bow and stem head and bolted strongly to both, but having struck the 'Cumberland' a glancing blow it was broken off. When she was docked after her fight, I put on a better ram of wrought iron and steel, extending back on her bows about 14 feet, which could not be knocked off.'"

The cut of this long ram is submitted with the firm belief that it is a true sketch of that instrument of naval warfare that was made for the "Patrick Henry" or "Jamestown." Mr. E. R. Archer, the present engineer of the Tredegar Iron Works, of Richmond, Va., who furnished this sketch, was assistant engineer of these works during the first years of the civil war, and says regarding this ram: "A ram was cast about the dimensions of the sketch I sent you. . . . It has been a long time since *I saw* the ram cast at these works." There is no doubt this ram was cast for the "Patrick Henry" or "Jamestown," as these vessels had receding stems, high freeboard, and long bowsprits, and it required a long ram where it was to be fitted two or more feet under water on such a vessel, to make it effective in offensive operations."

It will not be far from the truth to say that the engagement of the "Manassas" and "Richmond" was the cause of the adoption of the beak on the "Merrimac" and other later vessels of the Confederate States navy, and not until then was that fixture considered in the plans of any of their armored vessels.

The ram that was fitted to the Confederate ironclad "Arkansas," that was under construction at the same time as the "Merrimac," was of a peculiar form. It was made of cast iron, for in the early part of the civil strife the Confederacy were without the necessary tools to work heavy wrought iron. It was formed in the shape of a V to fit the bow of the vessel, and as fitted in place was about ten feet high and the sides four feet long and three inches thick, and fastened to the vessel by screw bolts. There was on the front of this casting an iron beak or projection about six or seven feet from the top, that was six feet long, ten inches thick at inboard end, and four inches at extremity. There was a similar ram prepared for use on the "Tennessee," a mate of the "Arkansas," but never put in place, as the vessel was burned while on the stocks just prior to the naval battle before Memphis, Tenn.

There were no other Confederate naval vessels fitted with these long iron beaks, for they gained experience from the loss of the one on the "Merrimac." Their vessels constructed later had a short and stout wooden ram built out from the stem of the vessel as a part of the structure, from the waterline to three feet below the surface of the water, and this was covered with the armor plating. This type of ram was on the "Albemarle" and the "Atlanta."

There was another ironclad of the type of the "Arkansas," but smaller, named "Albemarle," that demonstrated the usefulness of the ram in offensive operations when she sank the U. S. S. "Southfield" by ramming, when off the mouth of the Roanoke River, N. C., on April 19, 1864. This was the vessel that was a few months later destroyed by Lieut. W. B. Cushing, U. S. Navy, with a torpedo.

In taking account of these three fatal ramming occasions during the civil war, it is found that the U. S. S. "Richmond" was rammed during the night while the vessel was lying at anchor; the "Merrimac" rammed the U. S. sloop of war "Cumberland" while lying at anchor in Hampton Roads; and the "Albemarle" rammed the U. S. S. "Southfield" while both vessels were moving through the water toward one another in nearly opposite directions. The "Manassas" could not have been moving very rapidly when striking the "Richmond," or the damage would have been more extensive. It is no surprise that the "Merrimac" crashed through the side of the "Cumberland," which was anchored; and with the "Albemarle" and the "Southfield" approaching from opposite directions, the light-built converted ferryboat must give way under the crushing impact.

The first contract made for a vessel by the Union Secretary of the Navy, having a ram bow, was for the ironclad frigate "New Ironsides" on October 15, 1861. This ram was covered with the extension of the armor plating, and was 4½ feet deep, 9 inches thick, and projected 6 feet from the stem proper. The iron-hull turret gunboat "Keokuk," having a ram bow, was under construction before the "Monitor"-"Virginia" contest in Hampton Roads took place.

The first few years of the war there was a great difference of opinion regarding the best application of the ram to a seagoing vessel. Many considered that a vessel that was well strengthened in the bow, and the stem built to stand a crushing blow, was as well suited for ramming as another vessel having a bow built for the purpose and with a stem having a convex front and plated with heavy iron.

There were a few of the double-ender type of side-wheel naval vessels built in 1862 having a false metal stem or ram. The "Sassacus" was one of the number, and the only one of the type that had an opportunity to do any ramming during an engagement in the civil war. This was during the naval battle in Albemarle Sound with the Confederate ironclad "Albemarle" on May 5, 1864. The "Sassacus" "was shod with a bronze beak weighing fully three tons, well secured to prow and keel, and this was twisted and almost torn away in the collision," is in the report of an officer of the vessel of the engagement. There were twenty-seven of these wooden-hull vessels built for the Union Navy Department in 1862-3. The Bureau of Construction and Repair advises the writer that "no description of said ram other than appears on the plan of the 'Tacony,' a sister ship of the 'Sassacus,' can be found. A tracing has been taken from this plan showing the bow of the 'Tacony' with the ram attachment in place." There were a few others, in all probability, of this same type of vessel, with a similar ram attachment. They were the only wooden-hull naval vessels of the United States navy, not ironclad, that had a ram.

(To be continued.)

WHITE CEMENT.*

By A. G. Larsson, C.E.

Numerous experiments have been conducted, especially during the past three or four years, both on this continent and in Europe, in connection with the manufacture of white cement. The reason for this is that, in spite of the common Portland cement being an excellent building material for coarser work, such as foundations, sidewalks, etc., it is, on account of its dull gray color, of less avail for artistic work. The cementing material required for this purpose must be pure white and weatherproof, and need not have, as a rule, the strength of Portland cement. Plaster of Paris and magnesia cements have been used to some extent, but the former is not weatherproof, and the latter are not very reliable.

The coloring matter in Portland cement is oxide of iron, and sometimes oxide of manganese. To obtain a white color, the product should not have more than 0.80 per cent F_2O_3. With this limitation there are some difficulties. It is not an easy matter to find suitable raw materials. Even if the limestone is easy to locate, the clay, which must be china clay, is scarce, and when found is likely to be rather expensive. Then, again, a mixture low in Fe_2O_3 requires very high heat, and is, therefore, hard to burn.

Some of the experimenters have tried to make white Portland cement, and others to make white Roman cement. Both have succeeded. There are now factories for white Portland cement in the United States and Germany. The following analysis is of a sample from Stettin, Germany:

SiO_2	19.82 per cent
Al_2O_3	11.49 per cent
Fe_2O_3	0.67 per cent
CaO	61.60 per cent
MgO	0.72 per cent
So_3	1.99 per cent

The cement was sound, but was ground rather coarse. Mr. Julius Gresley, president of the Liesberg cement mill, Switzerland, has analyzed the best French Roman cements, and from these analyses he figures the following standard formula for his cement:

$$x\,[2\,(CaO.\,MgO).\,SiO_2] + y\,[2CaO.\,Al_2O_3] + z\,[CaO.\,SO_3]$$

The $CaO.SO_3$ is not necessary, but seems to make the mixture burn easier. This cement comes on the market under the name of "Marbrit."

The following analysis shows the proportions of this product:

Moisture	3.75 per cent
SiO_2	17.66 per cent
Al_2O_3	16.52 per cent
Fe_2O_3	0.74 per cent
CaO	54.69 per cent
MgO	0.53 per cent
SO_3	6.11 per cent

Specific gravity = 2.815.

The cement is sound, and ground fine, but is quick setting. Any kind of work will be hardened enough to release from its mold in two hours, or even sooner.

This cement possesses an advantage over the white Portland cement in that when it is strong enough for the purpose required it is easier to burn and cheaper to manufacture.

Dr. Delaire, a French physician, has just completed an interesting work by restoring a part of a face which was blown away by the bursting of a shotgun. The man had his chin, the lower part of his jaw, a portion of his tongue, and the whole of his upper jaw and nose blown away. The restoration, which is considered a marvel of mechanical as well as surgical ingenuity, has been exhibited before the Academy. From ten or fifteen feet distance the mechanical face appears quite natural, and the man is able to masticate his food and speak with comparative ease. Every day he takes off his artificial face and washes it with soap and water. The face consists of four parts. The first is a silver groove, into which some of the lower teeth are fixed. This is attached to a dental apparatus of tin, into which are fixed the remaining teeth. The second piece consists of a dental apparatus in vulcanite and gold for the upper row of nine teeth. This is fitted to two small protuberances, which fit into the nasal cavities. This also fills up the right sinus, which was smashed in. At the back is a piece of gold mechanism with hooks, used to fasten on the face piece. The third piece of the mechanical face consists of the chin and lower lip. This is of India rubber, painted to resemble nature. Over the chin a false beard is fixed. At the back are a couple of small bolts, which pass through holes in the teeth and fix the lip to the artificial lower jaw. The fourth and last piece of the apparatus consists of the upper lip and nose, also in India rubber, and painted, to which is attached a false mustache. At the back are two small clasps to which the upper dental piece and jaw are fixed.

* From the Canadian Cement and Concrete Review.

ENGINEERING NOTES.

On any hand-power-operated apparatus, such as a small jib crane, requiring a considerable exertion on the part of one or more men, the position and throw of the crank become important. Experience has shown that for the average laborer a height of shaft of 32 inches above the ground or platform, with a throw of 32 inches provided by a crank arm of 16 inches, is satisfactory. For an operation requiring only light exertion the crank length might be made only half this amount, and the crank shaft placed 40 inches above the floor level.—The Engineer.

An induction furnace, patented last year, is operated by a one or more phase current, and is provided with energizing or primary coils, constructed in tubular form, through which a cooling fluid is circulated. The coils are thus cooled, and the iron of the magnetic circuit is prevented from rising above the temperature at which the maximum permeability is obtained. The secondary circuit consists of a tube or channel containing the molten metal. This channel may be provided with appropriate windings for producing a rotary or shifting magnetic field, which will thus cause a circulation in the molten metal.

A competition for instruments designed to indicate the fuel consumption of automobiles has been instituted in France. According to the rules which have just been issued by the Association Automobile Generale of Paris, under whose auspices the trials will be held, the instruments must be capable of universal adaptation to all machines, and must constantly show the amount of fuel being consumed, as well as the speed of the motor while running. Competitors must submit drawings of their inventions, and also must demonstrate them on cars under standard test conditions. The first prize is $200.—The Engineer.

In its annual report last year the Hamburg Union of Shipowners drew attention to the fact that many of the mines which were laid out in Chinese waters during the late Russo-Japanese war, some of which are said to be still lying in places where they were originally sunk, while others are still floating about, continue to form a source of great danger to shipping, and that it must be greatly regretted that measures have not yet been taken for their removal. The Shipowners' Union hopes, however, that at the Hague Conference means will be adopted among the maritime governments to prevent the recurrence of such a state of things.

It is reported that during the course of a cruise from Melbourne to Sydney H. M. S. "Challenger" was able to keep in continuous wireless communication with the flagship H. M. S. "Powerful." The longest distance covered was 410 miles, the "Powerful" being at that time in Hobson's Bay and the "Challenger" in Farm Cove, Port Jackson. This distance, it is said, is the longest so far covered by warships on the Australian station. It is further stated that the commonwealth government intends to establish wireless communication between the Australian mainland and its new dependency Papua, formerly British New Guinea.

During 1906 there was a large increase in the shipping, steam and sailing, entered at Japanese ports. The number of steamers entered was 10,653 of 18,956,-596 tons, as against 7,833 vessels of 14,259,537 tons in 1905, an advance of 2,820 vessels and 4,697,059 tons, or nearly 33 per cent; 2,407 sailing vessels of 126,858 tons also entered, as against 2,217 vessels of 113,546 tons during the previous year, an increase of 190 ships and 13,312 tons, or over 12 per cent. The total was, therefore, 13,060 vessels of 19,083,454 tons, as against 10,050 ships of 14,373,083 tons in 1905, an increase of 3,010 vessels and 4,710,371 tons, or 32.8 per cent.

An important railroad development is to be carried out by the British Colonial Office in Nigeria, by means of which Baro and Kano will be connected, thus bringing the latter into direct communication with the sea *via* the Niger, the highest navigable point upon which is Bano. This railroad will be of 3 feet 6 inches gage, 400 miles in length and will cost approximately $15,000 per mile. The work of construction is to be undertaken by Sir Percy Girourard, the builder of the desert railroads of the Soudan, and it will occupy some four years. By means of this railroad the fertile belt of Nigeria, which is so favorable to the cultivation of cotton, will be tapped, and a decided impetus imparted to this industry, the experiments in which direction have so far proved eminently successful.

A vast dock improvement scheme has been commenced at Southampton. On a stretch of land reclaimed from the sea it is proposed to construct a huge basin, 1,700 feet in length by 400 feet in width. The outer walls to the dock will afford quay space for eight of the largest vessels afloat, while within the dock itself there will be available berths for four vessels, each 800 feet in length. The basin will be dredged to a depth of 40 feet at low tide, giving a depth of 53 feet at high water, so that vessels will be able to pass in and out of the basin at any state of the tide. This port already possesses three of the finest graving docks in the world. The new project has been decided upon as a result of the White Star liners coming to this port, combined with the fact that this company is embarking upon the construction of vessels of greater length and displacement than those already in service.

TRADE NOTES AND FORMULÆ.

To Extract a Watch Jewel.—A flat piece of pegwood is cut out, about the size of the jewel, on the side opposite the setting. The plate or bridge is placed above a hollow punch. A smart blow is given to the peg-wood pressing on the jewel. In this way the jewel may be kept intact, especially if of large or moderate size. It is a practical method for not damaging the setting.

Repairing a Cracked Dial.—Clean the crack carefully, cover the face of the dial with a little fine oil, and heat cautiously till the oil smokes; then place the dial on a flat surface and press on the cracked portion with a wooden handle, so as to tighten the crack as much as possible. Keep up the pressure until the dial is cold. This method will cause a small crack to disappear, or conceal in part a larger one.

To Clean the Works of a Watch or Clock.—A quart of water containing a piece of soap of the size of a nut, is boiled until the soap dissolves. When taken from the fire, a small quantity of ammonia is added. The movement, after repairing, is immersed in the solution. The wheels and small pieces are tied together with a strong thread, except the escape wheel, the lever, the lever cock, and the fly, for the sake of precaution. The barrels are tied with another thread. The plates are placed at the bottom of the vessel, and the balance at the top. The immersion should last for two or three minutes according to the heat of the water and the dirtiness of the pieces. When taken from the hot suds, the pieces are rinsed in benzine and put in lukewarm sawdust. They are shaken by means of the threads. When dry, a simple dash of the brush among the teeth and pinions will complete the cleaning. This method is expeditious.

Preservation of Belting.—In an iron vessel well covered 100 parts by weight of finely cut rubber is heated with 100 parts of refined turpentine oil at 50 deg. C. (122 deg. F.). When the rubber is dissolved 80 parts of colophony (rosin) are added; and when the rosin is dissolved, add 80 parts of beeswax; 300 parts of fish oil and 100 parts of tallow are put in another vessel of larger size. The mixture is heated till the tallow is completely melted. The contents of the first receiver are poured in and stirred continuously, until the matter cools and thickens. The inside of the belts while in motion may be rubbed with this lubricant. It gives the belts great stability, and in such condition they run easily on the pulleys without slipping. It also improves old belting. For this purpose it is applied on both sides, in a warm room. A first coating is given, and when thoroughly soaked in, a second is added. So treated, belts are more lasting and resisting.

Recent Gilding Processes Introduced in the Various Countries of Europe.—(Translated principally from the French, German, and Italian languages.)

One of the most recent processes is that of Sig. Bacciochi, of Italy. It relates to the production of fire-gilt or silvered plates and wires. Hatchings are made on the side to be gilt or silvered. After a thorough scrubbing, a caustic with a base of liquid silver is deposited. It is dried, and a coating of silver applied, which is covered with potassium cyanide. The articles are wrapped in hemp canvas and heated at 300 deg. C. When the wrappings are burned, the ingots, still hot, are passed to the polishing apparatus.

The metal called "Chemical Gold" in Europe is a compound of copper, zinc oxide, crystallized nitrate of baryta, zinc nitrate, minium, and zinc sulphophenate.

Preparation of an Electrolyte for Electro-Gilding.—A soluble gold salt and a soluble silver salt are dissolved in a solution of potassium cyanide. To the liquid is added an earthy alkaline salt, soluble in water (or calcium, barium, magnesium, or strontium salt) or an earthy salt (aluminium or glucinium) previously neutralized by a caustic alkali or an alkaline cyanide. Finally, the bath receives a proportion of nitric acid, determinable according to its concentration and the conditions of electrolysis. This is the process of A. Zags von Mazrimmen of Berlin.

Gilding of Metals by Spontaneous Reduction.—Dr. Göttig of Berlin has introduced a process by which gold chloride in aqueous solution is decomposed by sodium sulphide or sodium sulphocyanide. To the liquid is added alcohol or oxalic acid. With sodium or arsenic pentasulphide reddish deposits are obtained.

Plating of Gold, Silver, and Other Metals on Aluminium.—By the recent Hinque process, the aluminium surface is first covered with a coating of silver. A very thin gold or silver leaf is applied. It is then put in an annealing oven, heated to a temperature of from 250 deg. to 300 deg. C., and afterward subjected to the action of rollers to fasten the gold or silver leaf. The silvering coat is obtained by rubbing the aluminium surface with a powder consisting of cream of tartar, ten parts by weight; silver nitrate, ten parts; sodium chloride, one hundred and fifty parts.

SCIENCE NOTES.

A preliminary report has just been published by an expedition sent by the Smithsonian Institution last spring to investigate the great deposit of meteorites near Canyon Diablo, Ariz. The results thus far reached show that a new type of meteoric iron from the locality and a remarkable specimen of fused siliceous sandstone have been formed. They further bring out the fact that the several thousand pieces of meteoric iron already discovered on the spot landed on the earth before the last eruption of the volcanoes north of Flagstaff, Ariz., and perhaps coincident with the formation of a craterlike hole of considerable size, the origin of which has for some years been a matter of speculation. There remains the possibility, therefore, that several centuries ago either one huge mass of meteoric material or thousands of smaller masses struck the earth with such force at this spot in Arizona as to cause a depression in the surface of the land.

An official of the British Meteorological Office has communicated a report describing the striking of a captive balloon by lightning and the effects thereof. The balloon was aloft at the time with a number of meteorological instruments attached, being anchored by means of tinned steel piano wire to a winch on the ground. At the time of the discharge the balloon was at an altitude of about 3,500 feet, the length of wire paid out being approximately 4,500 feet. The winch from which the wire extended was earthed to a solid plate of iron buried to a depth of 18 inches. As a result of the flash the wire was severed, the balloon drifting away with the instruments, while the wire was carried to the earth, and in some places forced therein to a depth of two or three inches. The wire for about 750 feet from the winch was quite softened, bending easily, and was fused right off at the drum. According to the inspection that was subsequently made of the wire, it appears that the heat developed by the discharge, while not sufficient to fuse the wire, was yet adequate to melt the tinning.

An important paper has been brought before the Geological Society by the Rev. Prof. G. Henslow, M.A., F.G.S., on the Xerophytic Character of Coal-Plants, and a Suggested Origin of Coal-beds. Of the Palæozoic flora, the *Equisetites*, represented to-day by the sole genus *Equisetum*, are decidedly hygrophytic, if not hydrophytic. The ferns, which appear to have much resemblance to certain modern types, especially the *Marattiee*, seem to have lived under more or less similar conditions to the present; i. e., varying from the hygrophytic habit of *Hymenophyllum* to the xerophytic *Ceterach*. The *Cycadofilices*, *Cordaites*, etc., are decidedly xerophytic; and the same is the character of the *Lycopodes*, represented now by *Lycopodium* and *Selaginella*, and of *Psilotium*, *Salisburia*, and others. In fact, the characteristic feature of the great coal-forests was xerophytic, and the vegetation appears to be of an upland type. Illustrations were given from modern and Carboniferous plants to show the characters of leaf, root, and stem which separate these classes of plants. The position of coal-seams is accounted for by the action of earth-movement in late Carboniferous times, which threw the forest-bearing surface into shallow waves and troughs, which became gradually accentuated, the latter being gradually filled with sediment, on which, during intervals of rest, new forests-growth took place.

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